COLLEGE OF ENGINEERING

UNIVERSITY OF MICHIGAN

ANN ARBOR

WELDING OF SPECIAL MATERIALS

DATA - PROCEDURES

by
H. A. Ohlgren
J. G. Lewis
R. J. Hennig

January, 1955

ACKNOWLEDGEMENTS

A significant portion of the suggested specifications and procedures outlined in this manual are based upon research, development, and practices resulting from work supported by the United States Government. Much of this work was done under the sponsorship of the defense agencies and of the U. S. Atomic Energy Commission because of the requirements of these bodies for equipment fabricated from special materials.

Acknowledgement is made to the American Welding Society, American Society for Metals, Linde Air Products Company, and Revere Copper and Brass, Incorporated, for permission to reproduce and refer to certain tables and data appearing in the appendix.

The advice and suggestions of W. C. Truckenmiller, Associate Professor of Production Engineering, and of L. E. Wagner, Assistant Professor of Production Engineering, are gratefully acknowledged.

The authors wish to thank R. J. Annesser for his help in editing, and to express their appreciation to M. J. Sinnott, Associate Professor of Chemical and Metallurgical Engineering, to E. H. Young, Assistant Professor of Chemical and Metallurgical Engineering, and to D. V. Ragone and to C. W. Phillips, Assistant Professors of Metallurgical Engineering, for help and suggestions.

INTRODUCTION

The information contained in this compilation serves to describe various processes of welding as applied to nickel, copper, aluminum, titanium, stainless steels, stainless-clad steels, and carbon steels. This work is intended to serve as a reference manual for those responsible for the control of welding, especially of materials other than carbon steels.

This report is intended to be used in conjunction with existing welding codes and is intended to serve as an interim statement of information of limited scope until such time as this information may be superseded by the issuance of addenda to existing codes.

Information has been presented in this manual in the form of suggested specifications. The attempt has been made to summarize the knowledge available to the authors in a form which will permit the ready reference to the conclusions which the authors have reached after reviewing the material consulted in compiling this work. It is believed that a condensed form of presentation, such as that employed, will best serve the needs of those who wish to review suggestions made in concise form for the welding of those special materials considered in this manual.

It should be emphasized that the presentation of the information contained herein in the form of specifications is not intended to convey the impression that the authors have sufficient information or wisdom to draw up a comprehensive code suitable for all users. Rather, it should be noted that the use of the specification form has been adopted in order to provide a brief, unambiguous statement of the authors' opinions.

The procedures described refer to manual welding by the acetylene, arc, heliarc, or sigma processes applied to materials which in their unwelded condition meet the requirements of the guided bend tests described in the text. Procedures for welding carbon steels, although widely practiced with

respect to acetylene and arc methods, are included since the practice of heliarc or sigma welding upon these materials does not appear to be widely established. Procedures for welding nickel, copper, aluminum, and titanium alloys are suggested, and it is throught that other materials may be welded by the general procedures described when these procedures are adapted to the particular materials in question.

Qualification procedures, tests, and classifications for welders are suggested in detail. Quality controls, inspection requirements, and weld tests are described in appropriate sections. A suggested division of responsibilities and obligations between a fabricator of equipment and the owner of the equipment are outlined in such a manner as to serve as an aid in planning and implementing welding work to be done in the fabrication of equipment or structures.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd.)

C1.00 WELDING, GENERAL

1.01 SCOPE

1.02 Unless otherwise specified by the OWNER, all welding for fabrication or alteration of vessels shall be done in accordance with this specification. The FABRICATOR shall be responsible for the quality of welding done by his organization and shall conduct such tests as herein required.

1.03 C1.00 of this specification covers the general requirements for qualification of welders and the FABRICATOR'S responsibility.

1.04 C2.00 of this specification covers the qualification tests of welders for the welding of carbon steel shapes, plate, sheets, or pipe by Acetylene or Arc process, and the welding of High Alloy steel shapes, plate, sheets, or pipe by the Arc, Heliarc, Sigma or Acetylene Processes.

1.05 C3.00-C4.00 of specification covers the welding procedures to be followed in the shop and in the field for the welding of shapes, plates, sheets, pipe and tube by the various processes designated as appropriate for carbon steel, stainless steel, nickel and nickel alloys, "Durimet 20", illium, copper and copper alloys, aluminum and aluminum alloys, clad steels, and titanium and titanium alloys. Where the term "Stainless Steel" is used in this specification, plate and sheet shall conform to ASTM designation A-167 Grade 6, latest revision, and pipe shall conform to ASTM designation A-312 Type 347, latest revision unless otherwise specified.

1.06 C5.00 of this specification covers quality control on the welding of carbon steel shapes, plate, sheets and pipe by the Acetylene or Arc processes and on the High Alloy steel shapes, plate, sheets and pipe by the Arc, Heliarc, Sigma, or Acetylene processes.

1.07 C6.00 of this specification describes some safety precautions applicable to the work described.

1.08 C7.00 of this specification covers miscellaneous items pertaining to this specification, such as sample forms, sketches of welder's tests and tables of general welding procedure.

1.10 LIMITATIONS

1.11 The procedures, as defined and described herein, are intended to apply to the manual application of the Acetylene, Arc, Heliarc, or Sigma processes of welding and to the materials permitted under this specification which, in their unwelded condition, meet the requirements of the guided bend test.

1.12 Materials which are not covered in this specification, or which, in their unwelded condition, do not meet the requirements of the guided band test, may be welded provided special welding processes and test requirements are set up and approved in writing by the OWNER.

1.20 WELDER'S QUALIFICATIONS

1.21 All welding shall be done by welders properly qualified on the basis of the tests called for on C2.00 of this specification and in accordance with the procedures described in C3.00 and C4.00 of this specification. (See C5.00 for OWNER'S responsibility).

1.22 GENERAL WELDERS on work heavier than B.W.G. Number 10, but not over 3/4", shall be divided into three classes as follows:

CLASS 1 - Qualified for Arc welding of High Alloy steels and Arc welding of GENERAL WELDER, CLASS 2.

CLASS 2 - Qualified for all Acetylene and/or Arc welding, other than High Alloy steels, where test requirements

as defined in C5.00 of this specification call for radiographing or other tests, in addition to visual inspection.

CLASS 3 - Qualified for all Acetylene and/or Arc Welding, other than High Alloy steels, where test requirements as defined in C5.00 of this specification call for visual inspection only.

1.23 **SHEET METAL WELDERS** on work not heavier than B.W.G. Number 10 shall be divided into two classes as follows:

CLASS 1 - Qualified for all Arc welding of High Alloy steels and/or Arc welding of SHEET METAL WELDER, CLASS 2.

CLASS 2 - Qualified for all Acetylene and/or Arc welding other than High Alloy steels.

1.24 **PIPE WELDERS** shall be divided into three classes as follows:

CLASS 1 - Qualified for Arc welding of High Alloy Steel piping and for Arc welding of PIPE WELDER, CLASS 2.

CLASS 2 - Qualified for all Acetylene and/or Arc welding of piping, other than High Alloy steels in the process category or where test requirements as defined in C5.00 of this specification call for radiographing or other tests in addition to visual inspection.

CLASS 3 - Qualified for all Acetylene and/or Arc welding of piping, other than High Alloy steels in the process category or where test requirements as defined in C5.00 of this specification call for visual inspection only.

1.25 HELIARC WELDERS shall be considered as a separate type requiring special qualifications in addition to qualifications in CLASS 2, GENERAL or CLASS 2, PIPE welding and shall be designated as follows:

CLASS 1 - Qualified for all Heliarc welding of High Alloy steel pipes, flats and shapes with a wall thickness of 0.216" or less.

CLASS 2 - Qualified for all Heliarc welding of High Alloy steel pipes, flats and shapes with a wall thickness of over 0.216".

CLASS 3 - Qualified for Heliarc welding of High Alloy steel pipe, flats and shapes where the resulting joint will not be required to be fluid tight or will not be required to be tested by means other than visual.

NOTE: At no time shall it be permissible to assign a welder to work for which he is not properly certified. It shall be permissible to assign a welder to work of a lower class than that for which he is properly certified.

1.30 WELDER'S CERTIFICATE

1.31 Upon completion of the tests prescribed herein, each welder shall be provided with a certificate by the FABRICATOR and signed by the FABRICATOR, certifying to the type and class of welding for which he has qualified. (Suggested form for certificate is shown in Appendix-Plate 2.) This certificate must be carried on the welder's person at all times while on the job site and must be presented for examination when requested to do so by authorized personnel. Certificates shall remain in effect indefinitely unless:

(a) The welder is engaged continuously in a lower class of

welding for a period of three months. In this case the certificate shall be suspended and a new certificate for the class of work he is then doing shall be issued.

(b) Three welds made by any particular welder do not meet the inspection and test requirements as defined in C5.00 of this specification. In this case, the certificate is automatically revoked and the welder disqualified from further welding covered by this specification for a period designated by the OWNER. However, this period shall not be less than thirty (30) days. In the interim, he may, at the discretion of the OWNER, be certified for the next lower class of work.

(c) There is some specific reason to question the welder's ability. In this case, the certificate shall be suspended and the welder required to requalify for the class of work in which he is presently engaged. Failure to requalify shall revoke the certificate and disqualify the welder from further welding unless he passes the test for another classification. This second classification must be lower than the one for which he was disqualified.

1.40 IDENTIFICATION OF WELDER'S WORK

Each welder shall be assigned by the FABRICATOR an identifying symbol, which shall be metal stamped adjacent to welds which he makes, except pipe buried underground or in concrete shall not be stamped. In the case of seam welds, the stamp shall be adjacent to the weld at intervals of not more than three feet, but not on the side of the material exposed to process liquids.

1.50 RECORDS

1.51 The FABRICATOR shall maintain a record of the welders employed by him, showing the date and results of tests and the identification assigned to him. These records shall be certified by the FABRICATOR and accessible to authorized personnel. Copies of these records as required shall be provided to the OWNER for his job record. A suggested form is shown in the Appendix-Plate 1.

1.60 HANDLING AND STORAGE OF WELDING ROD

1.61 Satisfactory weld metal is achieved by adjusting not only the wire composition, but also the alloying elements through the electrode coating. These coatings serve a dual purpose. They stabilize the arc and improve the properties of the weld metal. Moisture content, minerals, ferro alloys and binder are factors of the arc characteristics of the rod. Some coverings pick up moisture readily. In order to insure uniform and satisfactory performance of the rod, care shall be taken to:

(a) Store all rods in a dry heated building.

(b) Stack the containers in a cabinet or rack in such a manner that the manufacturer's specifications are easily read.

(c) Leave the shipping containers sealed until ready to use the rod.

(d) Keep rod free of dirt, moisture, grease and oil.

(e) Keep rod in a tray and off the floor while using.

1.70 DEFINITIONS

1.71

OWNER - OWNER or his authorized representative.

FABRICATOR - Manufacturer or contractor doing fabrication or construction work for the OWNER.

Acetylene - Oxygen Acetylene (welder, welding).

Arc - Metallic Arc (welder, welding).

Heliarc - The inert-gas shielded arc-welding process using Helium or Argon and non-consuming tungsten electrode. Heliarc is the registered trademark of Union Carbide and Carbon Corporation. Equivalent processes are permissible at discretion of the OWNER.

Sigma - Inert-gas metal arc-welding process using small diameter continuously fed, bare, consumable electrode protected from exposure to atmosphere by either of the two monatomic gases. Argon and Helium, or a mixture of the two.

S.S. - Abbreviation for Stainless Steel.

M.S. - Abbreviation for mild steel (Carbon Steel).

ACHF - Alternating current high frequency.

DCSP - Direct current straight polarity.

DCRP - Direct current reverse polarity.

C2.00 WELDER'S QUALIFICATION TESTS

2.01 GENERAL

The following applies to all qualification tests:

2.02 Although stricter conditions must be observed if specified, the OWNER may reject any test if the weld:

(a) Is not reasonably uniform in appearance.

(b) Shows undercutting of 1/32" or over.

(c) Has gas or slag pockets in evidence; except that very small gas pockets and specks of oxide or slag, well dispersed, may be disregarded.

(d) Shows insufficient penetration.

2.03 Unless otherwise called for, test specimens shall be 1-1/2" wide and shall be selected as designated in the tests. (See Appendix-Plate 3.)

2.04 Test specimens shall have all welds machined or ground flush with the base metal, unless otherwise called for. Grinding shall be perpendicular to the direction of the weld.

2.05 Where radiographic examination is required, it shall be part of the qualification procedure and must be passed before the welder is certified.

2.06 Radiographs shall be submitted to the inspector for acceptance or rejection by comparison with a standard set of radiographs.

2.07 Where requested by the OWNER, test specimens may be subjected to the fluorescent penetrant (Zyglo) method of examination.

2.08 All bend tests shall be guided bend tests to 180°.

2.09 Where the guided bend test is required, the test jig shall conform to AWS Specification B 3.0, latest edition. (See Appendix-Plate 14.)

2.10 For purposes of explanation, it is presumed that an applicant will not take tests on both Acetylene and Arc welding at the same time.

2.11 Separate test records will be made for Acetylene and Arc welding tests, and for each different type and class of welding, except for Class 2 and 3 if the test is for General or Pipe welders. Applicants may qualify on Acetylene welding only in Class 2 or 3 in the following types: General, Sheet Metal, or Pipe.

2.12 Test welds on S.S. should be made using 347 SCb or 304 ELC (.030C max.).

2.13 Voltage and amperage for each application are given in tables in the Appendix.

2.14 Jigs or clamps will be used as required, if available. Otherwise, tack weld as necessary.

2.20 GENERAL WELDERS

This classification will cover the welding of sheet, plate, and shapes heavier than B.W.G. Number 10 (0.134"), but not over 3/4-inch.

2.21 CLASS 3

The following tests are intended to test a welder's proficiency in qualifying for all Arc or Acetylene welding other than High Alloy steels, where test requirements as defined in C5.00 of this specification call for visual inspection only.

(a) Butt Weld Test (Appendix-Plate 4).

Three pairs of plates 6" by 5" by 3/8" in size, shall be welded together along their 6" sides in a fixed position.

SAMPLE 1) Axis of weld horizontal with plates in a horizontal plane.

SAMPLE 2) Axis of weld vertical with plates in a vertical plane.

SAMPLE 3) Axis of weld horizontal with plates in a horizontal plane and welded from the bottom side.

Test coupons shall be selected as follows: Cut a strip 1" wide off the welded plates and discard it. Cut a second strip 1 1/2" wide as one test coupon. Cut a third strip 1" wide and discard it. Cut a fourth strip 1 1/2" wide as the second coupon and discard the remaining 1" strip.

Coupons shall be given the guided bend test. One coupon from each welding position shall be bent 180° from the root and one bent 180° from the face.

After bending, should a crack or other defect be present in the weld metal, or between the weld metal and the parent metal, which exceeds 1/8" measured in any direction, the test should be considered a failure. Cracks occurring at the edge of the coupon, not exceeding 1/8", shall be acceptable.

Five of the six coupons must be acceptable. If the sixth coupon develops a crack of more than 1/8" and less than 1/2", but in the opinion of the OWNER, the crack is not caused by a serious fault in the welding technique, the welder will be considered to have passed this test.

2.22 CLASS 2

The following tests are intended to test a welder's proficiency in qualifying for all Arc or Acetylene welding other than High Alloy steels where test requirements, as defined in C5.00 of this specification, call for mechanical tests in addition to visual inspection.

(a) Butt Weld Test (Appendix-Plate 4.)

Same as Butt Weld Test for Class 3 Welder.

(b) Fillet Weld Test (Appendix-Plate 5.)

Fillet weld along the 12" dimension a bar 3/8" by 2" by 12" to a bar 1/2" by 4" by 12". Half of the weld shall be made in a vertical position, the other half in the overhead position. Two test coupons shall be cut from each position welded.

One coupon from each welding position shall be nitric acid etched and examined for cracks, slag pockets, porosity and lack of penetration. The total length of all defects in the cross section of the weld shall not exceed 1/32 inch.

One coupon from each welding position shall be broken through the throat of the weld and examined for lack of penetration, porosity, slag, gas pockets and cold laps. The total length of all defects in either fractured surface of the weld shall not exceed 3/16".

2.23 CLASS 1

The following tests are intended to test a welder's proficiency in qualifying for all Arc welding of High Alloy steel plate and shapes.

(a) Required to have qualified for GENERAL WELDER, ARC, CLASS 2.

(b) Butt Weld Test Appendix-Plate 4.

Same as Class 2 Welder except using S.S. In addition, one coupon from each weld sample should be sent to the OWNER for testing for corrosion resistance.

(c) Fillet Weld Test - Appendix-Plate 5.

Same as Class 2 Welder except using S.S. In addition, one coupon from each weld sample should be sent to the OWNER for testing for corrosion resistance.

2.30 SHEET METAL WELDERS

This classification will cover the welding of materials of B.W.G. Number 10 (0.034") or lighter.

2.31 CLASS 2 - Appendix-Plate 6.

The following test is intended to test a welder's proficiency in qualifying for all welding, other than High Alloy steels.

The welder shall fabricate from 10 B.W.G. sheet metal, a rectangular tank 5" long, 3" wide and 2 1/2" deep. One side of the tank will have been prepared in advance with a 1/4" hole. To this hole shall be welded a 1/4" by 2" pipe. For visual acceptance, the OWNER shall require the welder to secure the following results:

(a) The base metal is in a fused state when the filler metal makes contact with it.

(b) The weld metal has not fallen through.

After visual acceptance by the OWNER, the tank shall be given a leak test. The tank shall be subjected to five pounds per square inch air pressure and then submerged in water. Liquid soap may be used instead of water to detect leaks. Any leak shall be considered a failure of the test.

2.32 CLASS 1 - Appendix-Plate 6.

The following tests are intended to test a welder's proficiency in qualifying for all arc welding of High Alloy steels.

(a) Required to have qualified for SHEET METAL WELDER, ARC CLASS 2.

(b) Fabricate from 20 gage S.S. sheet, a rectangular tank 5" long, 3" wide and 2 1/2" deep. One side of the tank will

have been prepared in advance with a 1/4" hole. To this hole shall be welded a 1/4" x 2" pipe.

For visual acceptance, the OWNER shall require the welder to secure the same results as for Class 2 and shall be given the same leak test. In addition, the box, after visual inspection and the leak test, shall be submitted to the OWNER for corrosion resistance test.

2.40 PIPE WELDERS

2.41 CLASS 3

The following tests are intended to test a welder's proficiency in qualifying for all welding of piping other than High Alloy steels, in the non-process category, or where test requirements, as defined in C5.00 of this specification, call for visual inspection.

(a) Butt Weld Test - Appendix-Plate 7.

Two pairs of 6-inch lengths of Schedule 40 Carbon Steel pipe, 6 or 8 inches in diameter shall be welded together in a fixed position. One weld shall be made in each of the following positions:

SAMPLE 1) Axis of the pipe in a horizontal position with the welding groove in a vertical plane. (The pipe shall not be rolled or turned during welding.)

SAMPLE 2) Axis of pipe in a vertical position with the welding groove in a horizontal plane.

Test specimens shall be selected as follows:

(1) From Sample (1) one specimen shall be removed from the top, bottom and side quandrants, at approximately 90° to each other.

Specimens shall be given the guided bend test. Specimens from the top and one side shall be bent 180° from the root, and specimens from the bottom and other side shall be bent 180° from the face.

After bending, should a crack or other defect be present in the weld metal, or between the weld metal and the parent metal, which exceeds 1/8" measured in any direction, the test shall be considered a failure. Cracks occurring at the edge of the specimen not exceeding 1/8", shall be acceptable. Three of the four specimens must be acceptable.

(2) From Sample (2) - two test specimens shall be removed at approximately 90° from each other.

Specimens shall be given the guided bend test. Specimen from the top shall be bent 180° from the root and specimen from the side shall be bent 180° from the face. One coupon must be acceptable.

(3) If the test specimens are passed by the OWNER, then one additional specimen shall be cut from each welding position which shall then be examined by radiograph.

2.42 CLASS 2

The following tests are intended to test a welder's proficiency in qualifying for all welding of piping, other than High Alloy steels, in the process category, or where test requirements as defined in C5.00 of this specification, call for radiographic examination or other tests in addition to visual inspection.

(a) Butt Weld Test - Appendix-Plate 7.

The Butt Weld tests will be the same as that for PIPE WELDER, CLASS 3, except that all weld coupons must be acceptable.

2.43 CLASS 1

The following tests are intended to test a welder's proficiency in qualifying for all Arc welding of High Alloy steel piping.

(a) Required to have qualified for PIPE WELDER, ARC, CLASS 2. In addition, one specimen shall be submitted to the OWNER for corrosion resistance test.

(b) Butt Weld Test - Appendix-Plate 8

The Butt Weld test shall be the same as for Class 2, except that 3/4" and 2" Schedule 40 S.S. pipe shall be welded and test specimen shall be 3/4" wide. In addition, two specimens shall be submitted to the OWNER for corrosion resistance test.

2.50 HELIARC WELDERS

1) Prepare a weld so that there is no clearance between lands to fill, or as nearly so as possible.

2) First pass use no filler. Use as many filler passes as necessary. Filler passes may not be necessary for some thin materials.

2.51 CLASS 3

The following tests are intended to test a welder's proficiency in qualifying for the Heliarc process for welding High Alloy steel pipe, flats, and shapes with a wall thickness of between 0.134" and 1/2" where said welding WILL NOT be required to be pressure tight in the process category and will only be subject to visual inspection.

(a) Required to have qualified for GENERAL WELDER, ARC, CLASS 2.

(b) Butt Weld Test - Appendix-Plate 4.

Same as for GENERAL WELDER, ARC, CLASS 3, except:

(1) material will be Stainless Steel.

(2) process will be Heliarc.

(c) Fillet Weld Test - Appendix-Plate 9.

Fillet weld a 5" square collar of B.W.G. Number 10 S.S. to center of a 6" length of 3" pipe, Schedule 40 S.S. on top side only. Inspect visually for reasonably smooth surface, undercutting and uniformity, top and bottom.

2.52 CLASS 2

The following tests are intended to test a welder's proficiency in qualifying for the Heliarc process for welding High Alloy steel pipe, flats and shapes having a wall thickness over 0.216"; piping being part of process category and/or where test requirements, as defined in C5.00 of this specification, call for tests in addition to visual inspections.

(a) Required to have qualified for PIPE WELDERS, ARC, CLASS 2.

(b) Butt Weld Test - Appendix-Plate 7.

Same as for PIPE WELDER, ARC, CLASS 2, except pipe will be S.S. of nominal diameter of 3" or more with a wall thickness to be about 0.375".

(c) Saddle Weld Test - Appendix-Plate 10.

Weld a 6" length of 3" pipe, Schedule 40 S.S., to the center of a 12" length of 5" pipe, Schedule 40, S.S. Axis of 5" pipe will be vertical and the axis of the 3" pipe will be horizontal.

The pipe will be cut along the plane in which axis of both legs lie. Nitric-acid-etch one half and examine for cracks, slag pockets, porosity and lack of penetration. The maximum length of any defect in the cross section of the weld will be 1/32".

2.53 CLASS 1

The following tests are intended to test a welder's proficiency in qualifying for the Heliarc process for welding High Alloy steel pipe, flats and shapes. These requirements apply to piping having a wall thickness less than 0.216", or to piping being part of the process category, and/or where test requirements as defined in C5.00 of this specification call for tests in addition to visual inspection.

(a) Required to have qualified for PIPE WELDER, ARC, CLASS 2.

(b) Butt Weld Test - Appendix-Plate 11.

One pair 1/2" Schedule 40 S.S. pipe and one pair of 2" Schedule 40 S.S. pipe, in 6" lengths, shall be butt welded together. Pipe will be held in a fixed position, axis of pipe horizontal.

The 1/2" pipe will be cut lengthwise for two specimens. Four specimens, 3/4" wide, will be cut from the 2" pipe at 90° to each other.

One specimen from each pipe will be nitric-acid-etched and examined for cracks, slag pockets, porosity and lack of penetration. The maximum length of any defect in the cross section of the weld will be 1/32".

The second specimen from the 2" pipe shall be given the Root bend test. The maximum length of any crack or other defect in the weld or between the weld and base metal will be 1/8".

If above tests are passed by the OWNER, then one specimen from each pipe shall be radiographed. A sufficient number of radiographs will be taken to examine the specimen completely.

If the radiographic test is passed, then the last specimen from the 2" pipe will be submitted to the OWNER for the corrosion test.

(c) Saddle Weld Test - Appendix-Plate 11.

Saddle weld a 1/2" pipe, Schedule 40 S.S., to a 2" pipe, Schedule 40 S.S. Hold pipes in a fixed position, the 1/2" pipe vertical and the 2" pipe horizontal.

Cut pipe along the plane in which the axis of both legs lie. Nitric-acid-etch one half and examine for cracks, slag pockets, porosity and lack of penetration. The maximum allowable length of any defect in the cross section of the weld shall be 1/32".

C3.00-C4.00 WELDING PROCEDURES

3.01 GENERAL WELDING PROCEDURES

3.02 Position work for flat welding wherever possible.

3.03 The sequence of welding shall be adjusted to minimum distortion and hot tearing. The OWNER may at any time prescribe the particular sequence.

3.04 A back step or wandering sequence shall be used when necessary, or when directed by the OWNER.

3.05 Welding shall not be done when surfaces to be welded are wet, or during periods of high winds, unless the work and the welder are properly protected.

3.06 The metal surfaces shall be cleaned of all scale, oxide, oil, grease, or other foreign materials to a distance not less than 1/2" from the weld edge.

3.07 No bevel or groove is required for butt welds on material 3/32" thick or less, excepting material to be welded by the Heliarc process.

3.08 All parts to be welded shall be securely held in correct relative position by jigs, clamps, wedges or other suitable devices, or by tack welds. Such devices shall remain in place until the work has cooled to room temperature. Tack welds shall be sufficient in number to prevent distortion. (Ref. Plate 12).

3.09 The welding current shall conform to both voltage and amperage and polarity for DC, as recommended by the manufacturer of the electrode being used.

3.10 The maximum size of the electrode for the first pass for all joints shall be 1/8" diameter to insure full penetration. Subsequent passes shall be

made with the largest diameter electrode possible, as limited by (1) good welding practice, (2) ability of welder, and (3) capacity of equipment.

3.11 Maximum size of fillet weld that may be made in one pass is 5/16".

3.12 On circumferential welds (pipes and vessels), the starting and completing tie of each pass will overlap and each tie will be staggered from the tie of the previous pass.

3.13 At no time shall the arc strike on the base metal, except for the first pass. After every interruption of the arc, except at the completion of a pass, the arc shall be restarted ahead of the previous deposit and then moved back to fill the crater. An alternate technique shall be used that will equally insure complete filling of the crater, complete fusion between the old and the new deposits and the base metal at the point of junction and complete resultant continuity of weld.

3.14 Before welding over previously deposited weld metal, all traces of slag shall be removed from the deposit, by chipping, if necessary and the deposit and adjoining base metal shall be wire-brushed until clean at all points. This requirement shall apply not only to successive beads, but to overlapping areas wherever a junction is made on restarting a bead.

3.15 When welding plates or shapes of unequal thickness, the arc shall be directed in such manner that both pieces being welded are heated equally.

3.16 Tack welds, if used, shall be of the same quality and made by the same procedure as the completed weld. They shall be made by the same class welder.

3.17 Cracks or slag holes that appear on the surface of any bead shall be removed by chipping or grinding before depositing the next successive

bead. Gas gouging shall not be used. Peening is also unacceptable. Holes or depressions in the last bead made by grinding, or chipping, will be filled to finish weld.

3.18 In multilayer welding, the several layers may be made successively, completing each layer before starting the next, or may be made by the "step" method. When the "step" method is employed, the length of each step need only be sufficient to provide a solid foundation of weld metal for the superimposed layer, except that if annealing of the underlying layers is desired, the length of each step shall be sufficient so that the starting end thereof will cool to at least a black heat before metal is deposited thereon.

3.19 All welded pipe joints shall have complete penetration to underside of weld with the absence of crevices. For this reason, a butt weld preparation is specified throughout, rather than socket preparation. Only in special cases, noted on drawings, are socket welds permitted.

3.20 Reinforcement of welds shall not be less than 1/32-inch or more than 1/16-inch. Reinforcement shall be free from depressions below the surface of the pipe.

3.21 Butt welds shall have finish bead width approximately 1/16 on each side of bevel.

3.22 All fillet welds will have 15% more design strength than smallest cross section of parent parts adjacent to joint.

3.23 In the case of piping, the welds shall be flush with inside of pipe. An even underhand thickness of 1/16-inch is allowed where grinding is not possible.

3.24 If doubts exist as to the nature of the joint or its preparation, the OWNER shall be consulted.

3.25 Do not grind or sand a smooth, flat surface on a completed weld, unless called for on drawing or by the OWNER.

3.30 CARBON STEEL

3.31 Scope

This specification is intended to define the general procedure to be followed for the manual and automatic welding of Carbon Steel shapes, sheets, plate or pipe, of all thicknesses, by the Arc, or Acetylene processes.

3.32 Filler Metal

(a) Arc Welding

All Arc welding electrodes shall conform to the requirements of the ASTM Serial Designation A233, latest revision Electrodes shall be of Classification Number 60, suitable for the positions of welding and other conditions of intended use.

(b) Acetylene Welding

All Acetylene welding rods shall conform to Classification GA-65 of ASTM 251 for iron and steel gas-welding rods.

3.33 Preparation of Base Metal

The work to be welded shall be accurately cut to size and shape by machining or shearing, or by flame cutting. If flame cutting is used, the edges cut shall be uniform and be cleaned from all scale, oxidation and slag accumulations.

Edges of material with a wall thickness greater than 3/32" prepared for butt welding shall be beveled at 37 1/2° ± 2 1/2°, leaving a 1/16-inch land at the bottom of the welding edge. Beveling of pipe shall preferably be done by machine.

A steel wire brush may be used for removing light rust and scale, but for heavy scale, slag, etc., a grinder, chisel, air hammer, or other suitable tool shall be used to obtain a bright, clean finish.

3.34 Fitting Up - Appendix-Plate 13

The edges of material at the joint shall be positioned as described below and in no case shall the edges be offset from each other at any point in excess of one quarter of the thickness of the thinnest section involved in the weld.

Shapes and Plate

(a) All parts to be joined by fillet welds shall be brought into as close a contact as practical.

(b) The separation between facing surfaces of lap joints and butt joints, landing on a backing structure, should not exceed 1/16".

(c) The space between edges in a butt joint should not exceed 3/32".

Piping

(a) All butt welds on pipe with wall thickness of .125, or lighter, shall be by Acetylene process. The space between edges in butt joints shall be 1/16" ± 1/32".

(b) Saddle welds shall be fitted up the same as butt welds.

(c) Welding neck flanges shall be fitted up the same as butt welds.

(d) Slip-on flanges shall have space from face of flange to end of pipe for fillet bead equal to thickness of pipe wall.

3.40 STAINLESS STEEL - ARC

3.41 Scope

This specification is intended to define the general procedures to be followed for the manual and automatic welding of stainless steel shapes, sheets, or plates of all thicknesses, or pipe heavier than 2" Schedule 40 by the arc or sigma processes. On pipe lighter than 2" Schedule 40 weld the first pass by means of inert arc welding with gas backing, and the remainder of the weld may be finished with metallic arc. The inert-arc first-pass-technique may be used for all thicknesses of pipe. These methods may be used for other stainless steel welding if approved by the OWNER.

3.42 Base Metal

Unless otherwise called for, the base metal shall conform to ASTM A-167, latest revision, for plate or sheet; to ASTM A-312, latest revision, for pipe, and to ASTM A-269, latest revision, for tube.

3.43 Filler Metal

On welding 347 or 304 ELC (.030 C Max.) S.S. the balanced electrode shall be used. This has a balanced 2 to 1 ratio, i.e., 19% Cr. and 9 1/2% Ni. (when using 19% Cr. rod with 10% or higher Ni, cracking is likely to occur).

The electric arc rod comes in two coatings which are lime or titanium oxide. On stainless steel, 347 SCb, titanium oxide-coated rod shall be used except for vertical down; lime-coated rod may be used in any position.

When welding 321 S.S., use 347 rod. (The titanium in 321 rod will oxidize out and not cross from electrode into the weld. Titanium will cross from the electrode to the weld in the Heliarc and Sigma processes).

Columbium stabilized 316 S.S. welding rod may be used for 304, 316, 317, and 321 stainless steels.

Do not use 347 for 316 stainless steel.

Do not use 308 for 316 stainless steel.

3.44 Fitting Up - Appendix-Plate 13

The edges of material at the joint shall be positioned as described below and, in no case shall the edges be offset from each other at any point in excess of one quarter of the thickness of the thinner material at the joint, for general welding, or one fifth of the thickness of the wall at the joint for piping.

Shapes and Plate

(a) All parts to be joined by fillet welds shall be brought into as close contact as practical.

(b) The separation between facing surfaces of lap joints and butt joints, landing on a backing structure, shall not exceed 1/16".

(c) For wall thickness up to 3/32", square the edge for a square butt weld.

(d) For wall thickness over 3/32" and to 1/4", bevel edge 30° and leave a 1/16" to 3/32" land at the bottom.

(e) For wall thickness over 1/4", use a "U" groove with 1/16" to 3/32" land, 3/16" to 5/16" radius and 20° taper sides. Adjust land and radius to size electrode being used.

NOTE: To prevent carbide precipitation during welding operation, a continuous water quench for heavy gage and air for light gage is advisable. When continuous quenching is not

possible, a wet rag may be used. If a step sequence is used, leave enough heat in the metal to vaporize all the water in order to prevent the porosity which will otherwise form in the pocket where welding ceased. Chill bars may be used without quenching, if approved by the OWNER.

3.45 STAINLESS STEEL HELIARC

3.46 Scope

This specification is intended to define the general procedure to be followed for the manual welding of S.S. plate, shapes and pipe by the Heliarc process.

The process described herein is for Argon gas, but Helium may be used as a shielding gas.

3.47 Base Metal

Unless otherwise shown on drawings, the base metal shall be ASTM A-167, latest revision, plate or sheet, ASTM A-269, TP-347, latest revision, tube and ASTM A-312, latest revision, pipe.

3.48 Equipment

The equipment required for Heliarc welding includes the following:

(a) An inert-gas shielded-arc welding electrode holder, which must have a water supply of 30 to 50 psi available for cooling. Approximately one pint of water per minute shall be used. High frequency superimposed current must be employed so that arc may be started without touching tungsten electrode to parent or weld metal. The arc shall be struck on a copper strip adjacent to weld.

(b) A standard AC or DC welding machine is used, depending upon whether AC or DC current is required for the particular type of welding. In the case of a DC machine, a separate voltage control is necessary. The AC machine must be of sufficient capacity so that it can normally be run at only 70% rated capacity.

(c) Argon tanks with suitable flow meters and pressure gages are needed. When the pressure on the tank is below 10 psig., it must be replaced.

(d) A suitable supply of cooling water is needed.

3.49 Preparation of Base Metal - Appendix-Plate 13

The work to be welded shall be accurately cut to size or shape by machining or by powder or by air arc cutting methods approved by the OWNER. When powder or air arc cutting is used, stock-removal of 1/32" minimum by filing or grinding shall be required. Edges prepared for butt welding must be beveled at 22 1/2° angle, leaving a 1/16" (+ 1/64", - 0") land on the bottom of the welding edge. Beveling shall be done by machining, except in the case of thin sections, which may be beveled with a file or grinder. No bevel is required on 16 B.W.G. or lighter. Edges prepared for a saddle weld must be prepared to fit closely together and have slightly beveled edges forming a slight groove and land. Welding neck flanges shall be prepared the same as for butt welding of pipe.

Preparation of Base Metal - Appendix-Plate 13

Only stainless steel wire brushes shall be used on stainless steel surfaces. Care must be exercised at all times when grinding not to raise the temperature above 850° F. where

carbide precipitation takes place rapidly. Machine cutting is preferred, air arc second, powder cutting third.

3.50 Fitting Up - Appendix-Plate 13

(a) Butt Welds

The welding edges shall be butted together so that the lands are touching and the beveled edges form a groove. No clearance between the lands is allowed. If the pieces cannot be held by alignment fixtures, tack welds may be made along the groove.

(b) Fillet Welds

The pieces to be welded shall be closely fitted together and held in position by jigs and clamps or by tack welding.

(c) Saddle Welds

The pieces to be welded shall be fitted up the same as for butt welds.

(d) Welding Neck Flanges

The pieces to be welded shall be fitted up the same as for butt welds. In fitting up, edges to be welded must be properly butted together so that there is no necessity for bridging any gaps with the weld.

3.51 Specific Welding Requirements

NOTE: For any special requirements, consult the instruction manuals published by the manufacturers of the inert gas welding equipment.

(a) Electrodes - Table 3

In order to produce a stable arc, the electrode should be out of the cup approximately 1/8" to 3/16". The distance from metal must be closely controlled by the operator to insure a steady stable arc. Care must be taken that the electrode does not touch the metal. If it does touch the metal, tungsten is usually included in the weld and must be ground out. Also a ball of tungsten alloy will form on the end of the electrode. This must be broken off and the electrode resharpened.

(b) Filler Rod - Tables 2 and 3

The filler rod shall be bare. The stainless steel filler metal shall conform to Classification E-347, ASTM Designation 298, latest revision. Stainless steel filler rods shall have the ends marked yellow (primary) with a blue band or spot (secondary). Where base metals not specified above are to be welded, the OWNER shall specify the type of welding rod to be used.

(c) Striking the Arc

The arc shall be struck between the electrode and a piece of copper plate located adjacent to the weld.

(d) Purging

The inside of the pipe shall be purged with Argon gas. The rate of Argon flow shall be sufficient to create a shield of inert gas around the molten metal as the lands are fused together. Argon gas shall be introduced at the lowest point in the pipe since it is heavier than air and will force air out of the high points of the system. At the start of purging, higher rates of Argon flow may be used for a few minutes.

(e) Welding

The minimum number of passes in pipe welded in any position shall be one (1) pass for each 1/8" of wall thickness. The first pass shall be

made with a slight weaving motion of the arc using no filler rod. The operator must control the speed of welding to secure complete penetration, and at the same time to insure that the underhang in the interior of pipe (that cannot be ground) does not exceed 1/16". The underhang shall be the absolute minimum obtainable with complete penetration. Purging shall be used during all passes. In additional passes, filler rod shall be used. The arc shall be moved diagonally back and forth across the groove. The filler rod shall be dipped in the previous puddle with an intermittent motion so that the molten metal will form puddles in the groove and overlap the base metal presenting a convex bead along the weld. In order that oxidation cannot occur on the filler rod, it must not be pulled out of the inert atmosphere during the operation. The last pass will be made without filler rod, using a weaving motion, to finish weld to a relatively smooth surface. If chill bars are impractical because of the design, or water quench cannot be used, a wet rag may be used for cooling. After welding a few inches, the wet rag may be applied; sufficient heat should be left in the metal to vaporize all the water, otherwise porosity will form in the pocket where welding ceased. Preventing carbide precipitation which occurs between 850° F. and 1600° F. is very important. Maximum allowable time at this range is one (1) minute for type 304 S.S. and seven (7) minutes for type 347 S.S. SCb.

(f) Stopping the Arc

To stop the arc, the rate of travel shall be increased along the unwelded portion of the groove and the electrode quickly broken away by pulling it from the work. Incorrect breaking of the arc will cause burning of the weld.

(g) First Pass Welds

All first pass welds shall be made without filler rod.

3.60 NICKEL ALLOYS

3.61 Scope

This specification is intended to define the general procedures to be followed for the manual welding of Nickel Alloy plates, shapes, or pipe; by the Arc or Heliarc welding process.

In general, the welding processes used for carbon steels are applicable, with slight modifications, to Monel, Inconel, and other related alloys.

3.62 Base Metal

Specifications for Nickel Alloys are as given by International Nickel Company, Inc.

3.63 Equipment

(a) Arc Welding

Equipment for arc welding of Nickel Alloys is standard equipment, as used for carbon steels.

(b) Heliarc Welding

Equipment for the Heliarc welding of Nickel Alloys is identical to that used for welding S.S. as given in 3.48 of this section.

(c) Acetylene Welding

Equipment for Acetylene welding of Nickel Alloys is standard with special fluxes.

3.64 Surface Preparation

All foreign material shall be removed for a minimum of 2" from the edge of the weld. The cleaned area shall extend beyond where the heat of

the weld will penetrate. When repairing or adding to existing piping, it may be necessary to cut through the pipe to clean the inside.

To insure satisfactory welding, it is necessary to remove the thin oxide film from the immediate vicinity of the area to be welded. This can be done by such mechanical methods as machining, grit blasting, grinding, rubbing by hand with emery cloth, or by chemical treatment. This need for oxide removal prior to welding is due primarily to the dissimilarity of melting points of the base metal and the oxide.

Oil, grease, or shop dirt containing sulphur shall be removed by scrubbing with trichlorethylene or equivalent solvent. If lead or a sulphur is present in paint, it shall be removed with a paint solvent remover or by rubbing with abrasives. Polishing and/or grinding are often necessary to remove imbedded material, such as caustics.

3.65 Joint Preparation - Appendix-Table 5

The work to be welded shall be accurately cut to size and shape by machining or powder cutting methods approved by the OWNER. When powder cutting is used, a minimum of 1/32" shall be removed by filing or grinding. Care shall be exercised that all burned and heat affected material is removed from the joint.

Material up to 0.109" thick may be welded with a square butt joint. For material up to 3/8" thick, the edge shall be beveled at 40°, leaving a 1/16" land. For material up to 3/4", a 15° side angle with a 5/16" radius bottom and a 1/8" land shall be used. Deep penetration and the necessarily attendant high heat input should be avoided as much as possible.

3.66 Filler Rod - Appendix-Table 2

See Table 2 for proper rod for Arc or Heliarc welding. Only 1/8" diameter or larger, 132 Inconel rod, may be used with the AC Arc welding process.

3.67 Fitting Up - Appendix-Table 5

See Table 5 for space between lands for Arc welding. For Heliarc welding, butt lands tight together. Use jigs and clamps if available, otherwise tack weld as necessary.

3.68 Preheating

In general, preheating is neither required nor recommended, but, if the air temperature is at or below freezing, preheat to 70° F. for 6" on both sides of joint.

3.69 Arc Welding

Use DC with reversed polarity, except that when using 1/8" diameter or larger 132 Inconel rod, AC transformer equipment may be used. The weld metal does not spread, as in welding steel, but must be placed where required, which makes it necessary to weave the electrode slightly.

In other respects, Arc welding of Nickel Alloy is essentially the same as for steel.

3.70 Heliarc Welding

Helium is preferred to Argon as it (1) produces a sounder weld, and (2) permits higher welding speed. However, Argon is preferred for small parts and thin sections as it permits lower Arc voltage and, therefore, lower heat input.

Direct current, straight polarity is recommended for manual welding. A high frequency current should be super-imposed on the regular DC current for starting purposes.

Heliarc welding of Nickel Alloy is otherwise essentially the same as for stainless steel.

For complete instructions, consult "Technical Bulletin T-2" published by the International Nickel Company, Inc.

3.71 Acetylene Welding

In general, the Acetylene process will be found to be best suited to the welding of pipe or tubing less than 2" in diameter, regardless of wall thickness and for tubing with a wall thickness less than 1/8", regardless of diameter.

For complete instructions, consult "Technical Bulletin T-2" published by the International Nickel Company, Inc.

3.80 "DURIMET 20"

Available information on welding of "Durimet 20" is incomplete at this time, but a manufacturer of it has made the following recommendations:

3.81 Use a single "V" groove for 100% penetration where the other side of the joint is inaccessible for grinding.

3.82 Use the metallic Arc welding process.

3.83 Use a double "V" joint where both sides of the joint are accessible for welding and grinding.

3.84 Use a very sharp edge at the bottom of the groove.

3.85 S = 1/42" (space between abutting edges). See Plate 13.

3.86 Use a 1/16" diameter rod for all first passes. Never use larger than 1/8" diameter rod for succeeding passes.

3.87 Avoid puddling of weld.

3.88 Heat treatment: heat to 2050° F. and quench with water.

3.90 ILLIUM ALLOY

Insufficient information is available at present to permit specifying a procedure, but the manufacturer has made the following recommendations:

3.91 Use a double "V" groove with 1/16" maximum land.

3.92 Preheating is usually unnecessary where the pieces are rigidly clamped together. When this is not possible, heating to approximately 1400° F. (bright red heat) is recommended. Preheating in furnace permitting carburization is not recommended.

3.93 Build up total depth of weld in one pass where possible. When multiple passes are necessary, all slag must be chipped and brushed away and each succeeding layer must fuse deep enough into the preceding layer to float out all oxides and impurities.

3.94 When joining long sections, weld short sections at intervals.

3.95 When welding tubular sections, tack weld and progressively weld circumference.

3.96 Metallic Arc Welding

Metallic arc welding is recommended for most general welding work. The following items should be noted:

Use heavily coated electrode.

Use reversed polarity direct current.

Maintain shortest possible arc.

Good results have been obtained with 45 to 50 volts, 80 to 90 amps. and a 1/8" electrode.

3.97 Oxy-Acetylene Welding

Gas welding may be used for welding illium if the following precautions are observed:

Use a slightly reducing flame.

Use cast iron type flux, low in boron.

Use tip one size larger than for comparable welding of steel.

Use illium "G" alloy filler rod.

Point filler rod at completed weld at 45° angle.

In completing weld, remove flame slowly to permit progressive solidification from bottom.

4.00 COPPER AND COPPER ALLOYS

4.01 Scope

This specification is intended to define the general procedures to be followed for the manual welding of Copper and Copper Alloy plates, shapes, or pipe; by the Arc or Acetylene welding process.

4.02 Base Metal

Unless otherwise called for, the base metal shall conform to ASTM B-248, latest revision, plate or sheet, and ASTM B-251, latest revision, pipe or tube.

Welding of oxygen-bearing copper is not recommended.

4.03 Filler Metal - Appendix-Table 10

Brass alloys should be welded with aluminum bronze filler rods when maximum properties are required and with phosphor bronze filler rods when lower strengths are acceptable. Copper-silicon alloys may be welded with either silicon bronze or phosphor bronze filler rods. Copper-tin

alloys may be welded with phos-bronze filler rods. Copper-aluminum alloys should be welded with aluminum bronze filler rods of equivalent composition. Copper-nickel alloys should be welded with cupro-nickel filler rods of like composition. Copper-beryllium alloys should be welded with coated beryllium copper filler rods containing 1.1% nickel and 2.5% beryllium.

Filler rods shall conform to ASTM B-259, latest revision.

Metal arc-welding electrodes shall conform to ASTM B-225, latest revision.

4.04 Joint Preparation - Appendix-Tables 6, 7, 8, 9

Copper alloys under 3/16" may be square butted, generally. For brass over 3/16", use 45° single or double vee. For silicon bronze over 3/16", use 45° single or double vee for carbon arc and 60° single or double vee for metal arc. For aluminum bronze between 5/32" and 3/8", use 60° single vee; over 3/8", use 75° double vee.

Generally, backing strips of the same composition as the base metal are used, although copper, carbon, or asbestos, are satisfactory with most alloys.

4.05 Preheating - Appendix-Table 10

Preheating temperatures vary greatly, depending on alloy content. The following are intended only as general indicators:

Deoxidized copper	(lower temperatures with heavier section)	800° - 1400° F.
Brass	(higher temperatures with increasing zinc content)	400° - 700° F.
Silicon bronze		150° F. maximum
Phosphor bronze		300° - 400° F.
Aluminum bronze	(higher temperatures with increasing aluminum content)	400° - 800° F.

Cupro-nickel	150° F. maximum
Beryllium copper	600° - 700° F.

4.06 Post Heat-Treatment

In general, only the highest strength copper alloys are heat-treated. High alloy aluminum bronzes are annealed at 1150° F. and rapidly air-cooled. Beryllium copper is annealed at 1450° F., water-quenched, and drawn at 600° F.

4.10 ALUMINUM AND ALUMINUM ALLOYS

4.11 Scope

This specification is intended to define the general procedures to be followed for the manual welding of Aluminum and Aluminum Alloy plates, shapes, or pipe by the gas or arc welding processes.

4.12 Base Metal

Unless otherwise called for, the base metal shall conform to ASTM B-209, latest revision, plate or sheet; ASTM B-241, latest revision, pipe; ASTM B-210, or ASTM B-235, latest revision, tube.

4.13 Filler Metal - Appendix-Tables 11, 12, 13, 14

The filler metal should usually be the same composition as the base metal. For applications where corrosion-resistance is important, a very careful selection of filler rod is essential to correct for alloy loss during welding. The magnitude of the loss is dependent on the process used, flux composition and speed of welding. In general, there will be small losses (5-10%) of copper and silicon and larger losses (15-30%) of magnesium and zinc.

When corrosion and color matching is not a problem, a 5% silicon aluminum rod may be used.

Metal arc-welding electrodes shall conform to ASTM B-184, latest revision.

4.14 Joint Preparation - Appendix-Table 11

All foreign substances must be removed from the welding area. For inert gas arc-welding, the oxide film must be removed by abrasive cleaning or acid dip*. For other welding processes, the flux employed is sufficient for oxide removal.

It is essential to design joints so that all flux and oxide may be removed (or permanently sealed for lap joints) after welding. The presence of flux near the weld will seriously impair the corrosion resistance of the weldment. Inert-gas arc-welding is recommended for difficult-to-clean weldments.

Material under 0.081" should be welded only by the gas-welding or inert-gas arc-welding process. Welding of sheets under 0.040" is not recommended. Grooved backing strips are recommended for flat work.

4.15 Preheating

Preheating is recommended for all weldments over 1/32" section. Preheat temperatures vary from 250° F. for very light material to 600° F. for heavy sections to be joined to smaller components.

---

*Sulfuric acid following a caustic etch is preferred to nitric acid.

4.16 Post-Welding Treatments

All the high-strength aluminum alloys require heat-treating to recover maximum properties. A solution-anneal (890° to 970° F.) followed by water-or-air-quenching and sometimes by low-temperature aging (200° to 250° F.) restores good strength and corrosion-resistance.

It is essential that all flux be removed after welding. Immersion in boiling water and scrubbing with a fiber brush is often satisfactory. When joints are inaccessible from both sides, one of the following acid dips may be employed:

10% sulfuric acid - room temperature - 30 minutes.

5% sulfuric acid - 150° F. - 5 to 10 minutes.

10% nitric acid - room temperature - 10 to 20 minutes.

The efficiency of the cleaning operation shall be checked by the following method:

Apply distilled water to joint.

Allow two minutes solution time.

Collect one drop.

Place in 10% silver nitrate solution.

White precipitate indicates halide ion from flux.

4.20 CLAD STEELS

4.21 Scope

This specification is intended to define the general procedures to be followed for the manual or automatic welding of Alloy Clad Steel plate, sheet, or strip, by the inert-gas arc-welding process.

4.22 Base Metal

Unless otherwise called for, the base metal shall conform to ASTM A-263, latest revision, chromium steel clad: ASTM A-264, latest revision, chromium-nickel steel clad: ASTM A-265, latest revision, nickel and nickel-base alloy clad.

4.23 Filler Metal - Appendix-Table 15

In cases where corrosion is severe, the filler metal for the clad side shall be of such composition as to duplicate the base metal after welding. Frequently, a filler rod of higher alloy content is necessary to correct for dilution by the backing steel.

For making welds from the backing steel side only, it is necessary to use 25% Cr-20% Ni filler rod for all types stainless cladding to maintain weld ductility.

Metal arc-welding electrodes for welding of chromium and chromium-nickel cladding shall conform to ASTM A-298, latest revision.

Filler rods for backing steel may be of any composition which will provide required mechanical characteristics. Usually, a filler metal similar in analysis to the backing steel is used. Occasionally, especially on light sections normally requiring only one pass, the complete weld may be made with the alloy rod.

4.24 Joint Preparation - Appendix-Table 16

In the heavier plate, it is essential to maintain alignment to prevent excessive back-chipping and grinding and consequent over-consumption of high alloy electrodes.

When welding blind joints, use 45° - 60° single vee groove, full thickness, and 1/16" root spacing. Use a grooved copper backing strip.

Square butt joints are used for the lighter sheets to about 11 gage. From 11 gage to 3/16", bevel steel backing 45°, allowing sufficient root stock to prevent penetration to cladding. For plate over 3/16", use 60° single vee groove, maintaining 1/16" root stock above cladding. For automatic welding from the backing steel side, a square butt joint with 1/32" root spacing is used for plate to 3/8".

Edges may be prepared by the various machining or oxygen cutting techniques. Shearing and punching is done with the clad side up. Machining operations utilize lower speeds than for mild steel; a firm feed is essential to prevent surface work-hardening of the cladding material.

4.25 Preheating

Preheating to 300° to 400° F. is used for the following:

Heavy plates.

High strength backing materials.

Plates clad with any straight chromium steel except type 405.

Preheating may be done locally at the weld zone.

4.26 Welding Procedures - Appendix-Tables 16, 17

(a) General

When welding backing steel with mild steel electrodes, adequate care must be taken to prevent penetration to the cladding material. Electrodes of smaller diameter than for welding of steel are used to control penetration. When the backing side is welded first, the clad side is prepared by grinding or chipping to clean weld metal.

Never deposit mild steel on alloy welds or cladding; diffusion will take place and an extremely hard and brittle zone will result.

(b) Manual

Light sheets, to 16 gage, are welded in one pass from the clad side. Heavier stock is welded in one or more passes from each side. Material under 10 gage is welded with alloy rod exclusively. Stock over 10 gage may be welded with mild steel electrodes on the backing side.

(c) Aircomatic Process

Sheet and plate up to 3/8" thick are welded in a single pass from the backing side with an alloy electrode. Heavier stock is welded in one or more passes from each side using either mild steel or alloy rod for the backing side, which is welded first; or in several passes from the clad side using alloy rod exclusively.

Satisfactory results have been obtained by the single pass technique utilizing the following conditions:

Current	500 amps.
Voltage	30 volts
Travel speed	14-18 inches/minute
Gas	Argon, with up to 40% He
Gas flow	90 cubic feet/hour
Wire diameter	5/64 inch
Wire analysis	25 Cr - 20 Ni (19 Cr - 9 Ni)

For heavier plates using multiple passes, lighter currents and voltages are used for the clad side, steel side remaining the same as above.

4.27 Post-Weld Heat-Treatment

To relieve the major portion of welding stresses and develop maximum properties, the following heat-treatments are used:

Heat to prescribed temperature and hold for one hour per inch of thickness.

Furnace cool.

Straight-chromium stainless	1150° - 1200° F.
Chromium-nickel stainless	1100° - 1150° F.
Nickel-base alloys	1150° - 1200° F.

Stainless grades stabilized with columbium or titanium, or containing extra low carbon may be given a normal stress relief treatment.

4.30 TITANIUM AND TITANIUM ALLOYS

4.31 Scope

This specification is intended to define the general procedures to be used for the manual or automatic welding of Titanium and Titanium Alloy plates, shapes or tube; by the inert-gas arc-welding process.

4.32 Base Metal

Unless otherwise specified, the base metal shall conform to ASTM B-265 Grade 1, latest revision; with the exception of the metallic alloy content which shall conform to the manufacturer's specification.

4.33 Filler Metal

The filler metal shall be of similar analysis to the base metal. When welding rods are not available from the manufacturer, they may be cut from suitable sheet material.

4.34 Joint Preparation

All foreign substances must be removed from the heated area. Grease removal with carbon tetrachloride or trichlorethylene, followed by light etching with 0.5% hydrofluoric acid is recommended.

For stock up to 1/8" thick, use a square joint with no gap. For material 3/16" thick and heavier, use a 45° bevel, 1/16" root face, and 1/32" to 1/16" root gap. For butt joints on flat stock, a heavy slotted copper backing bar is recommended.

4.35 Welding Procedure - Appendix-Table 18

In general, most of the techniques and precautions used in inert-gas welding of stainless steel are applicable to welding of titanium and its alloys. It is particularly essential that the heated metal be protected from the atmosphere at all times. High flow rates of high-purity shielding gas over front and back, and use of a trailing shield are mandatory for maintenance of weld ductility.

4.36 Heat-Treatment - Appendix-Table 19

The all-alpha alloys and alpha-beta alloys containing less than 3% beta-stabilizing elements should show good physical properties in the as-welded condition. The higher-strength alloys may be heat-treated to improve the ductility.

C5.00 QUALITY CONTROL

5.01 SCOPE

The welding work to be performed under this specification is of extreme importance and must be of the highest quality. To this end, it shall be the responsibility of the OWNER, or his duly authorized representative, to establish a consistent welder qualification program, to supervise the welding tests and to insure compliance with all details of design, fabrication and tests specified by this specification, drawing, or other related documents, for all welding procedures and quality requirements.

5.10 RIGHTS RESERVED TO THE OWNER

5.11 Welder's Qualification Test

The controls under this heading shall permit the OWNER to:

(a) Stop the test weld if the applicable welding procedure stated in this specification is not followed, or if suitable results are not being obtained.

(b) Grant, at his discretion, approval for a retest to be given a candidate who has failed in his qualification test.

5.12 Shop Welding

The controls under this heading shall permit the OWNER to:

(a) Consult the FABRICATOR to define and establish the work classifications, procedures and welding sequences. This is especially important on all welding of High Alloy steels.

(b) Check the Welder's Qualification Certificates for compliance with the requirements of the work classification to be done as prescribed in C2.00 of this specification.

(c) Establish a program of continuous visual inspection.

(d) Establish a program of continuous spot testing or sampling, as required either by radiographing and/or by the fluorescent penetration method (Zyglo) and/or corrosion resistance.

(e) Accept or reject all work performed under this specification.

5.20 RESPONSIBILITIES OF FABRICATOR

The FABRICATOR shall afford the OWNER or his duly authorized representative:

(a) All reasonable facilities for testing and inspection.

(b) Free and unlimited access to all work being performed under this specification, including all tests of materials, etc.

Nothing contained or implied in this specification shall be construed to relieve the FABRICATOR from his responsibility for workmanship and materials acceptable to the provisions of our final specification.

5.30 QUALITY REQUIREMENTS

Welds having one or more of the following defects shall be rejected:

(a) Undercutting adjacent to completed weld, or evidence of undercutting removed by grinding and/or other means.

(b) Evidence of peening.

(c) Weld is not reasonably uniform in appearance.

(d) Obvious gas pockets or slag inclusions are present.

(e) Cold-lapping is evident.

(f) Weld profiles are not within the accepted tolerance.

(g) Less than 100% penetration for the entire length of the weld.

(h) Underhand in excess of 1/16" on inside of pipe.

(i) Craters resulting from improper breaking of the arc.

(j) Cracks.

(k) Welds do not meet the required tests.

(l) Tack welds made by an unqualified welder.

The approval of the OWNER shall be required before any defective welds are repaired. Welds which in the opinion of the OWNER cannot be successfully repaired, shall be cut out, prepared anew and rewelded.

5.40 INSPECTION REQUIREMENTS

All welding may be subject to inspection both during and after welding is completed. The inside welds of piping that are inaccessible for direct inspection shall, when so required by the OWNER, be examined by means of a "Boro-Scope", or equivalent. Defects so discovered shall be carefully noted as to exact location by quadrants and shall be corrected by chipping, or grinding, and rewelded.

The provisions under the heading of "QUALITY REQUIREMENTS" shall determine the acceptability of all welds inspected.

It shall be the responsibility of the welding supervisor and the OWNER to see that each welder uses the correct type filler rod for the material being welded.

5.50 TESTS

5.51 Radiograph

(a) Welds to be radiographed shall be as designated on the drawing, or by the OWNER. Wherever any doubt exists as to the quality of welding, the welds shall be subject to examination by radiographing, or by a fluorescent penetrant method, at the request of the OWNER. Trepanning shall not be done. However, a section of pipe containing a questionable weld may be removed for examination. In such a case, a new section of pipe shall be used as a replacement. Specimens representing a different welder's work for each test should be radiographed if possible.

(b) A sufficient number of radiographs shall be taken so that the weld will be completely examined.

(c) Unless the OWNER is an experienced radiograph technician, he shall submit the radiograph to a specialist for interpretation.

(d) When radiographs are taken as designated in 5.51 above and defects are shown, at least two additional radiographs shall be made of the same welder's work to determine his qualifications for the particular classification in question.

5.52 Fluorescent Penetrant (Zyglo)

The OWNER may require "Zyglo" type inspection of any weld.

C6.00 SAFETY PRECAUTIONS

6.01 GENERAL

The high temperatures used in welding pose certain hazards not encountered in other fabrication and maintenance processes. The following precautions are common to the various welding procedures:

Inflammable materials shall be removed sufficiently far from the welding area to preclude damage from sparks and metal spatters.

The operator shall be fully protected from the heat and glare as well as from sparks and spatter; a full covering, including body clothing, gloves, hat, and goggles or face mask, are essential.

Shields or screens shall be used as needed for protection of other workers.

Adequate ventilation shall be provided to remove metallic vapors and flux fumes. Special precautions in the form of respirators or face masks shall be used when welding materials containing toxic elements such as beryllium, lead or zinc, or with fluxes containing fluorides.

In maintenance and repair work, and particularly when cutting or patching lines and containers, adequate care shall be taken to insure absence of explosive fumes and volatile liquids.

6.02 ARC WELDING

The chief sources of danger in arc welding processes are ultra-violet radiation and electric shock.

The highly penetrating radiation necessitates wearing of heavy clothing to prevent skin blistering. The eyes, being particularly vulnerable, shall be protected by special glass filters.

To protect against electric shock, both the operator and the work area should be kept perfectly dry and the operator shall be insulated from the ground. The electrode holder shall be completely insulated; for high frequency alternating current, special holders are recommended. The welding machine shall be grounded to direct ground when possible; when connecting to metal structures, precautions are taken to insure adequate current-carrying capacity and low electrical resistance.

6.03 GAS WELDING

The main hazards in gas welding are the presence of the oxygen and combustible gases used in the various processes. A complete set of safety rules covering the use, handling and storage of compressed gas cylinders has been compiled by the Compressed Gas Manufacturers' Association; adherence to this code is recommended.

C7.00 MISCELLANEOUS

7.01 APPENDIX

Plate 1 - Record of Welder's Qualification Test (Form)

Plate 2 - Welder's Certificate (Form)

Plate 3 - Test Specimen - General

Plate 4 - Welder's Test - General Welder - Class 1 and 3

- Heliarc Welder - Class 3

Plate 5 - Welder's Test - General Welder - Class 1 and 2

Plate 6 - Welder's Test - Sheet Metal Welder - Class 1 and 2

Plate 7 - Welder's Test - Pipe Welder - Class 2 and 3

- Heliarc Welder - Class 2

Plate 8 - Welder's Test - Pipe Welder - Class 1

(Butt Weld Test)

Plate 9 - Welder's Test - Heliarc Welder - Class 3

(Fillet Weld Test)

Plate 10 - Welder's Test - Heliarc Welder - Class 2

(Saddle Weld Test)

Plate 11 - Welder's Test - Heliarc Welder - Class 1

(Butt Weld Test)

Plate 12 - Pipe and Flange Clamps - Typical

Plate 13 - Joint Details - Preparation and Fitting Up

Plate 14-A - Test Jig

Plate 14-B - Test Jig Details

Plate 14-C - Test Jig Details

7.01 APPENDIX (Cont'd.)

PLATE I

RECORD OF WELDER'S QUALIFICATION TEST (FORM)

TEST NO. _____

(FABRICATOR)

(ADDRESS OF PLANT; HOME PLANT IF TEST IS PERFORMED IN FIELD)

RECORD OF WELDER'S QUALIFICATION TEST

AS SPECIFIED BY IDAHO OPERATIONS OFFICE, U. S. ATOMIC ENERGY COMMISSION, IDAHO FALLS, IDAHO IN BULLETIN 6F8.

NAME _____ MARK _____

CLASS (1,2,3) _____ MATERIAL SPECS. _____

TYPE (GENERAL, SHEET METAL, PIPE, HIGH ALLOY) _____ FILLER ROD SPECS. _____

PROCESS (ARC, SIGMA, HELIARC, ACETYLENE) _____ PIPE, PLATE, OR SHAPE _____

SPECIMENS NO.	SPECIMENS DIMENSIONS	AXIS OF PIPE OR PLANE OF PLATE	AXIS OF WELD	SEE NOTE 2	TYPE OF TEST	PASS TEST YES-NO	REMARKS

1. PRIOR TO CUTTING SPECIMENS FROM SAMPLE, STAMP OR PAINT NUMBER ON FACE NEAR WELD. ALSO STAMP WELDER'S MARK ON FACE OF EACH SPECIMEN. IF NUMBER AND/OR MARK IS REMOVED BY MACHINING OR GRINDING, REPLACE SAME UPON COMPLETION OF OPERATION.

2. IN THIS COLUMN NOTE; (A) "OVERHEAD" FOR OVERHEAD WELDS ON PLATES OR FORMS, AND (B) "TOP", "BOTTOM", OR "SIDE" FOR SPECIMENS CUT FROM PIPE WELDED WITH AXIS HORIZONTAL.

3. ALL GUIDED BEND TESTS WILL BE NOTED AS TO TYPE, I.E., "FACE", "ROOT", OR "SIDE".

4. VISUAL TESTS WILL BE SIGNED FOR IN "REMARKS" COLUMN IF CHECKED BY OTHER THAN SIGNER OF STATEMENT NO. 2 BELOW.

STATEMENTS

1. I CERTIFY THE SAMPLES WERE PREPARED AND WELDED ACCORDING TO INSTRUCTIONS SET DOWN BY THE CONTRACTING OFFICER IN BULLETIN 6F8. I FURTHER CERTIFY THAT ALL SPECIMENS WERE PROPERLY PREPARED, PER ABOVE BULLETIN, AND NUMBERED, AND THAT ALL ENTRIES IN ABOVE TABLE, COLUMNS 1 THRU 6, ARE ACCURATE. I ALSO CERTIFY THAT WELDS TESTED WERE MADE BY ABOVE NAMED WELDER, UNAIDED BY ANYONE, AND IN THE ACCEPTED MANUAL MANNER.

SIGNATURE AND TITLE _____

DATE _____ EMPLOYED BY _____

2. I TESTED THE ABOVE SPECIMENS AND CERTIFY THE RESULTS AS STATED, EXCEPT THE VISUAL TESTS WHICH HAVE BEEN SIGNED FOR IN THE "REMARKS" COLUMN. I FURTHER CERTIFY TESTS WERE CONDUCTED AND EVALUATED ACCORDING TO SPECIFICATIONS SET DOWN BY THE CONTRACTING OFFICER IN BULLETIN 6F8.

SIGNATURE AND TITLE _____

DATE _____ EMPLOYED BY _____

PLATE 2

WELDER'S CERTIFICATION (FORM)

WELDER'S CERTIFICATE

NAME _____

MARK _____

HT. _____ WT. _____ EYES _____ HAIR _____

IS CERTIFIED AS QUALIFIED FOR FOLLOWING TYPES AND CLASSES OF WELDING AS DEFINED BY IDAHO OPERATIONS OFFICE, ATOMIC ENERGY COMMISSION IN BULLETIN 6F8

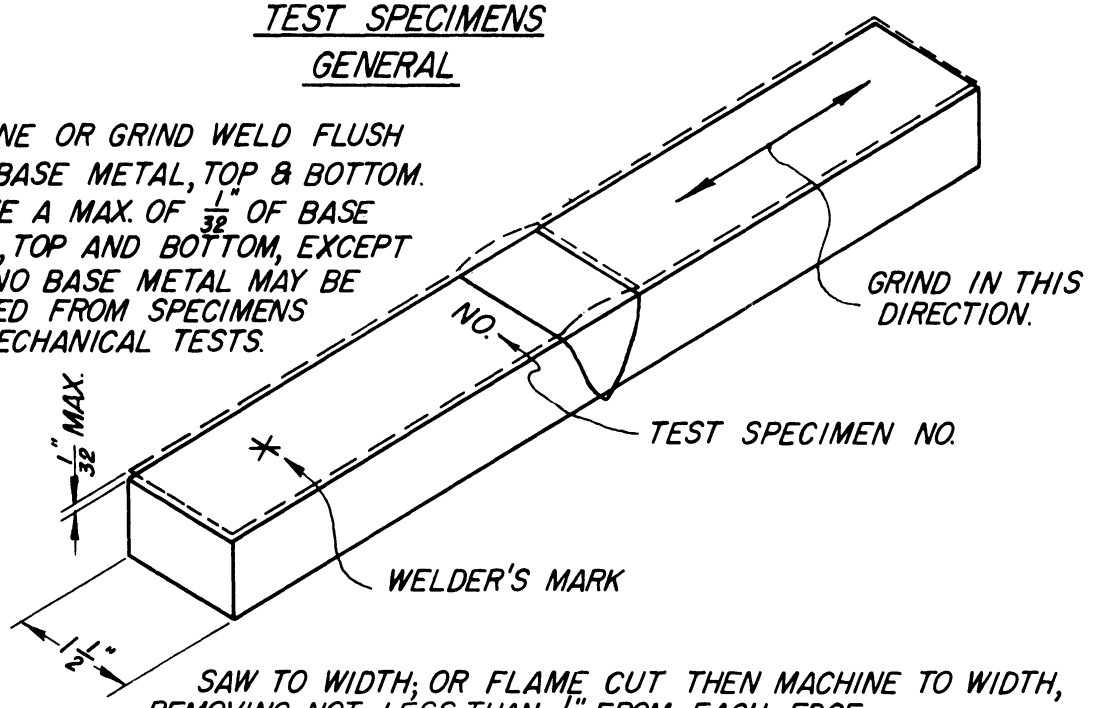
TYPE AND PROCESS	CLASS 1	CLASS 2	CLASS 3
GENERAL WELDER - ARC			
GENERAL WELDER - ACETYLENE	XXXX		
SHEET METAL WELDER - ARC			XXXX
SHEET METAL WELDER - ACETYLENE	XX		XXXX
PIPE WELDER - ARC			
PIPE WELDER - ACETYLENE	XXXX		
HELIARC WELDER			

CERTIFIED BY _____

SIGNATURE _____ DATE _____

PLATE 3
TEST SPECIMENS
GENERAL

MACHINE OR GRIND WELD FLUSH WITH BASE METAL, TOP & BOTTOM. REMOVE A MAX. OF $\frac{1}{32}$" OF BASE METAL, TOP AND BOTTOM, EXCEPT THAT NO BASE METAL MAY BE REMOVED FROM SPECIMENS FOR MECHANICAL TESTS.



SAW TO WIDTH; OR FLAME CUT THEN MACHINE TO WIDTH, REMOVING NOT LESS THAN $\frac{1}{8}$" FROM EACH EDGE.

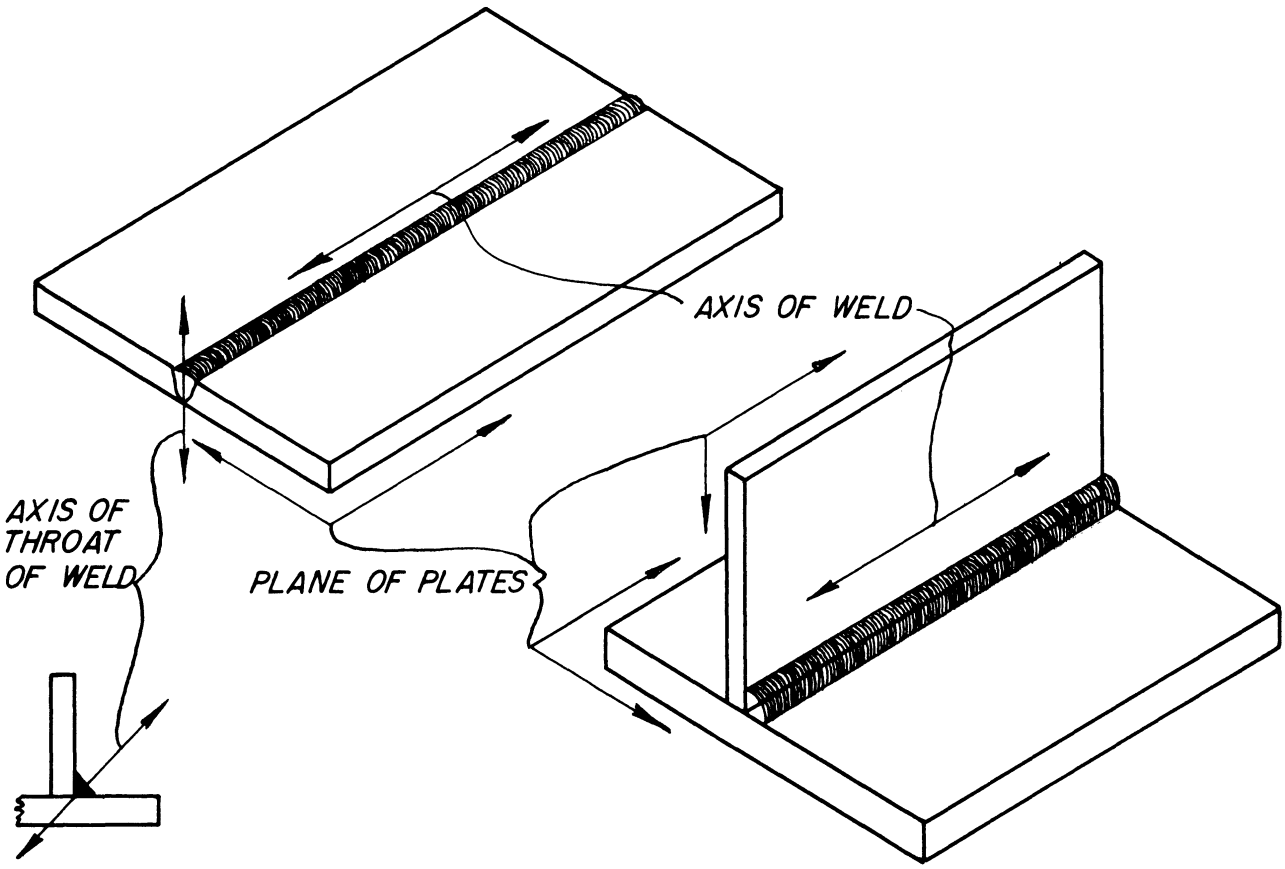
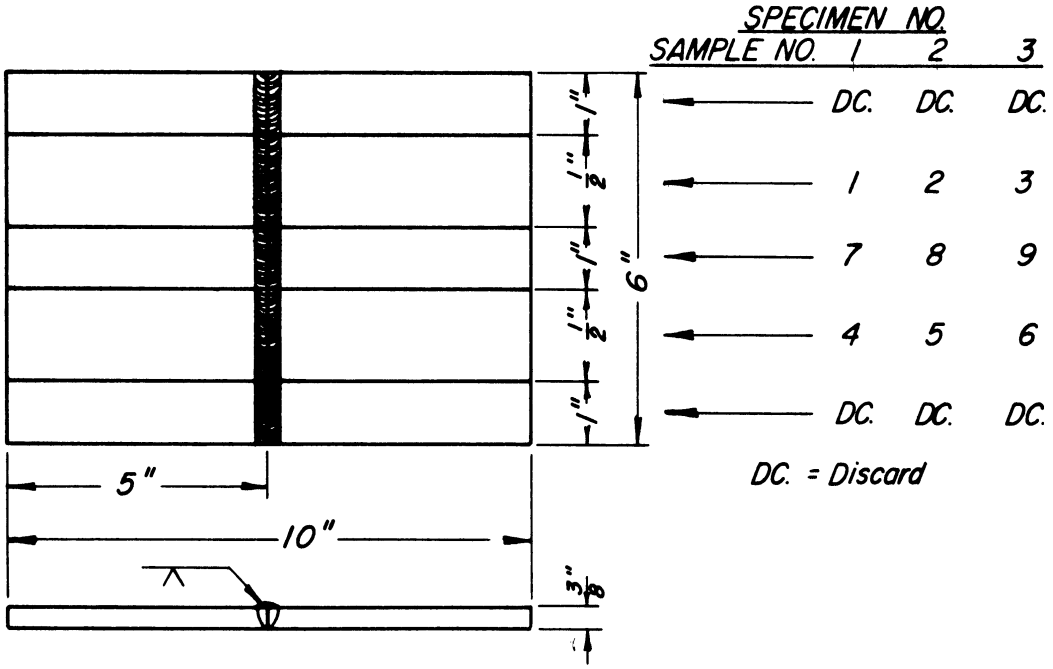
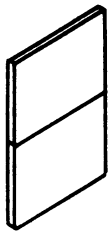


PLATE 4

WELDER'S TEST
GENERAL WELDER - CLASS 1 & 3
HELIARC WELDER - CLASS 3



DC. = Discard

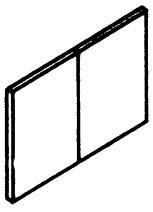


SAMPLE 1
PLATES - VERTICAL
WELD - HORIZONTAL

MATERIAL

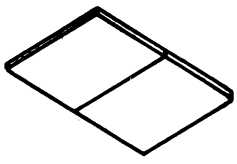
GENERAL WELDER - CLASS 1	S.S.
GENERAL WELDER - CLASS 3	M.S.
HELIARC WELDER - CLASS 3	S.S

6 - BAR $\frac{3}{8}$" x 5" x 6"



SAMPLE 2
PLATES - VERTICAL
WELD - VERTICAL

TESTS
SPECIMEN NO. 1,2,3 FACE BEND TEST
SPECIMEN NO. 4,5,6 ROOT BEND TEST
SPECIMEN NO. 7,8,9 CORROSION TEST,
1. for GENERAL WELDER - CLASS 1 ONLY.

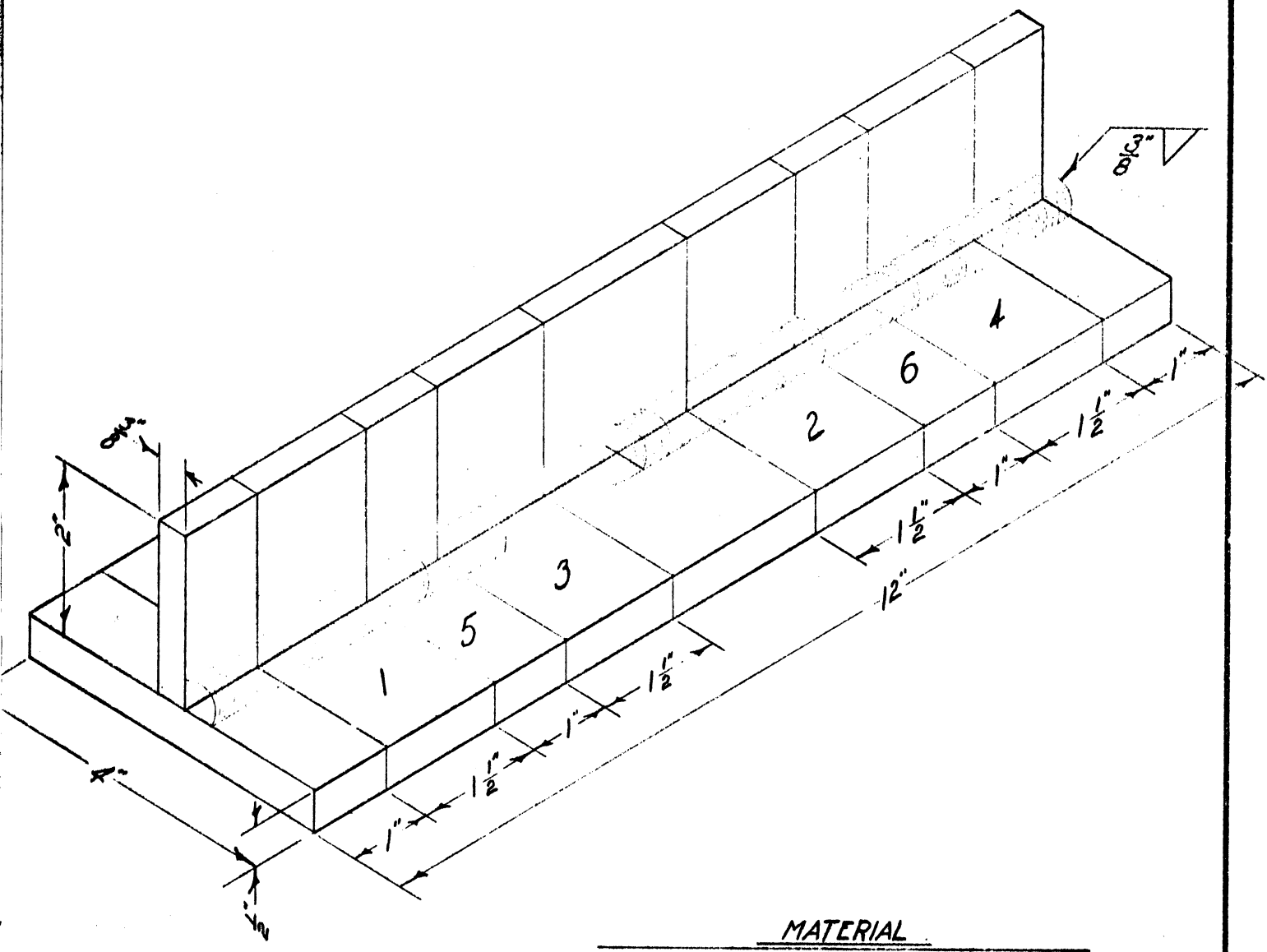


SAMPLE 3
PLATES - HORIZONTAL
WELD - HORIZONTAL & OVERHEAD

PLATE 5

WELDER'S TEST

GENERAL WELDER - CLASS 1 & 2



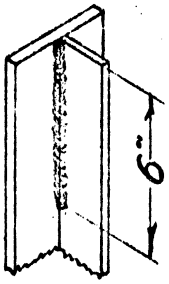
MATERIAL

CLASS 1	S.S.
CLASS 2	M.S.
1 - BAR 3/8" x 2" x 12"	
1 - BAR 1/2" x 4" x 12"	

TESTS

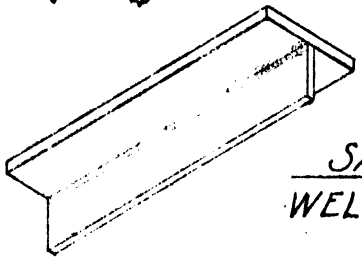
SPECIMEN No. 1,2	NITRIC ACID ETCHED
SPECIMEN No. 3,4	BREAK THRU THROAT
SPECIMEN No. 5,6	CORROSION TEST,

1. for CLASS 1 ONLY



SAMPLE 1

WELD - VERTICAL



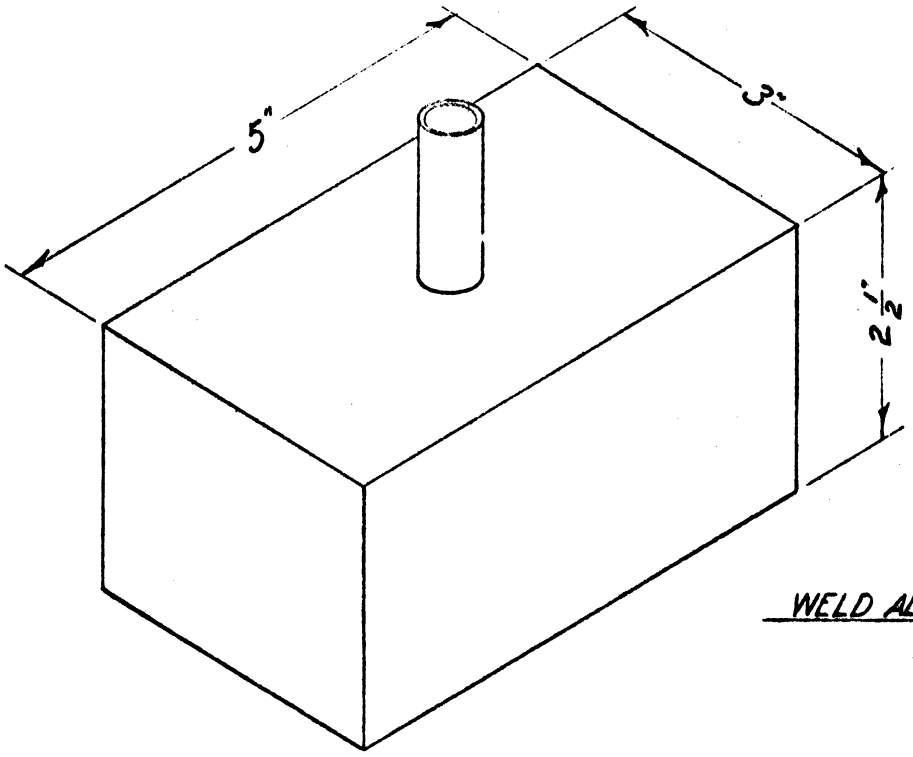
SAMPLE 2

WELD - OVERHEAD

PLATE 6

WELDER'S TEST

SHEET METAL WELDER - CLASS 1 & 2



WELD ALL SEAMS

MATERIAL

CLASS 1 — 20 Ga. S.S.
CLASS 2 — 10 Ga. M.S.
2 - SIDES 2½" x 5"
2 - ENDS 2½" x 3"
1 - TOP 3" x 5" — DRILL ¼ Dia. IN CENTER
1 - BOTTOM 3" x 5"
1 - NIPPLE ¼" x 2" M.S.

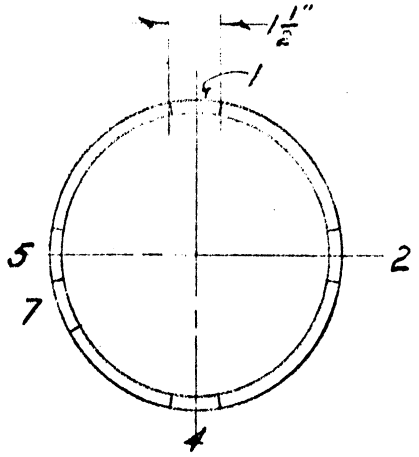
TESTS

1. VISUAL TEST
2. PRESSURE TEST - AIR AT 5 PSI
3. CORROSION TEST,
   1. for CLASS 1 ONLY

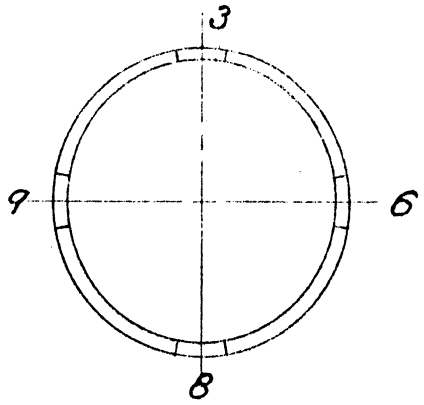
PLATE 7

WELDER'S TEST

PIPE WELDER - CLASS 2 & 3
HELIARC WELDER - CLASS 2

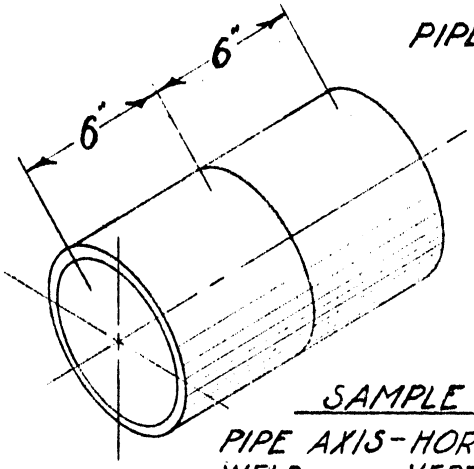


SAMPLE 1



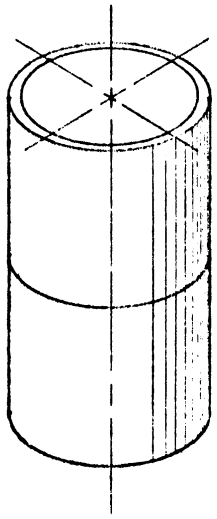
SAMPLE 2

PIPE WILL BE HELD FIXED WHILE WELDING, BOTH SAMPLES.



SAMPLE 1

PIPE AXIS - HORIZONTAL
WELD - VERTICAL



SAMPLE 2

PIPE AXIS - VERTICAL
WELD - HORIZONTAL

MATERIAL

PIPE WELDER - CLASS 2 & 3
6" or 8" PIPE, Sch. 40 M.S.
HELIARC WELDER - CLASS 2
3" PIPE, Sch. 40, or LARGER, S.S.

TESTS

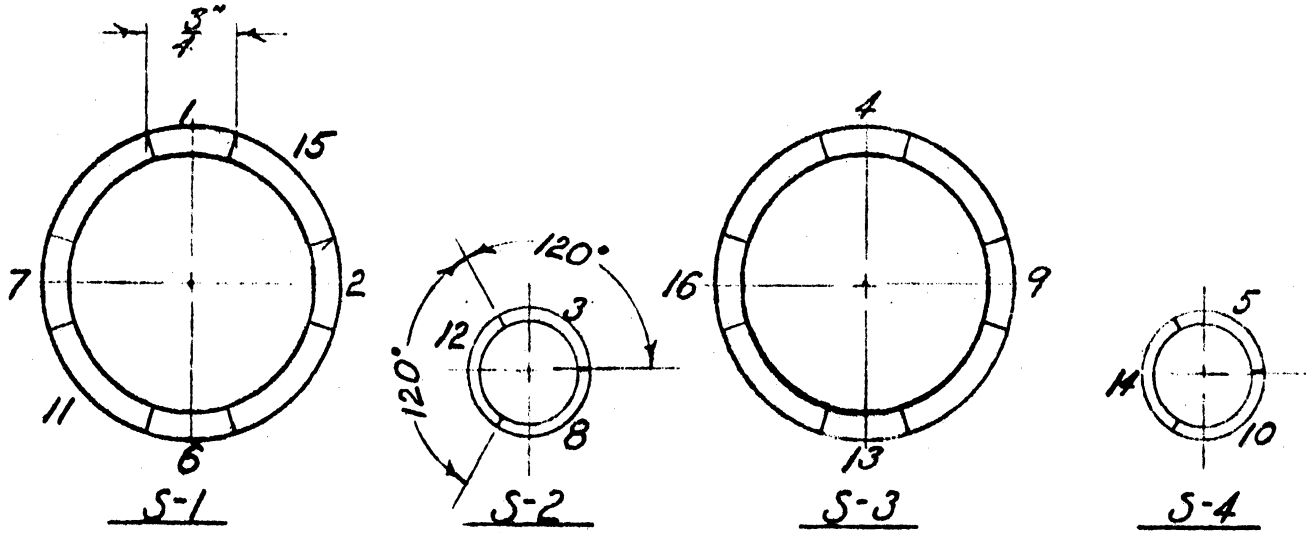
SPECIMEN No. 1, 2, 3 - ROOT BEND
SPECIMEN No. 4, 5, 6 - FACE BEND
SPECIMEN No. 7, 8 - RADIOGRAPH
SPECIMEN No. 9 - CORROSION TEST,
1, for PIPE WELDER - CLASS 1 &
HELIARC WELDER - CLASS 2

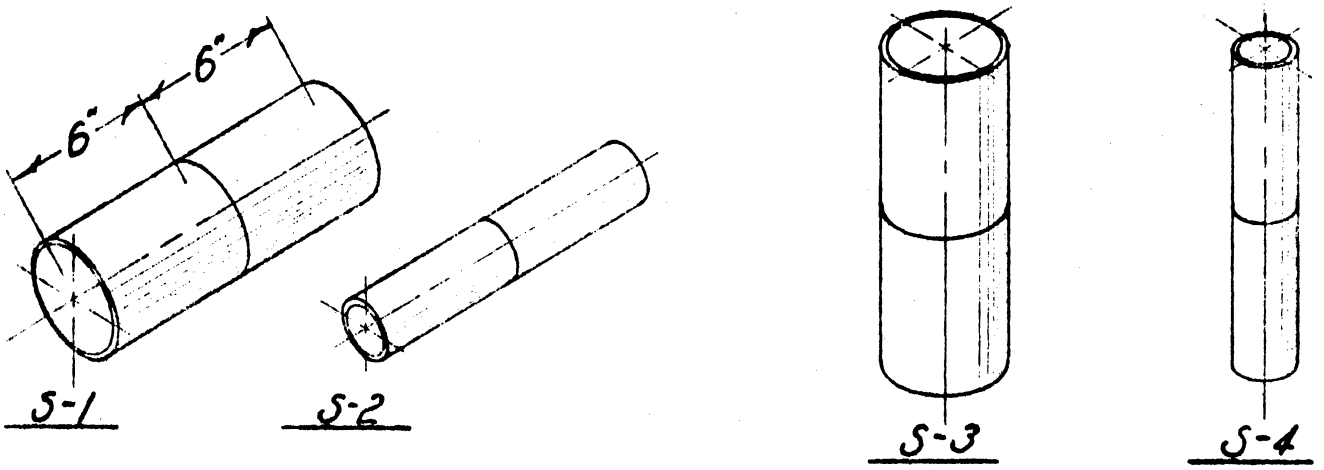
PLATE 8

WELDERS' TEST

PIPE WELDER - CLASS 1

BUTT WELD TEST





PIPE WILL BE HELD FIXED WHILE WELDING, ALL SAMPLES.

MATERIAL

4 - PIPE 2" x 6", Sch. 40, SS.
4 - PIPE ¾" x 6", Sch. 40, SS.

TESTS

SPECIMEN No. 1,2,3,4,5 - ROOT BEND
SPECIMEN No. 6,7,8,9,10 - FACE BEND
SPECIMEN No. 11,12,13,14 - RADIOGRAPH
SPECIMEN No. 15,16 - CORROSION TEST

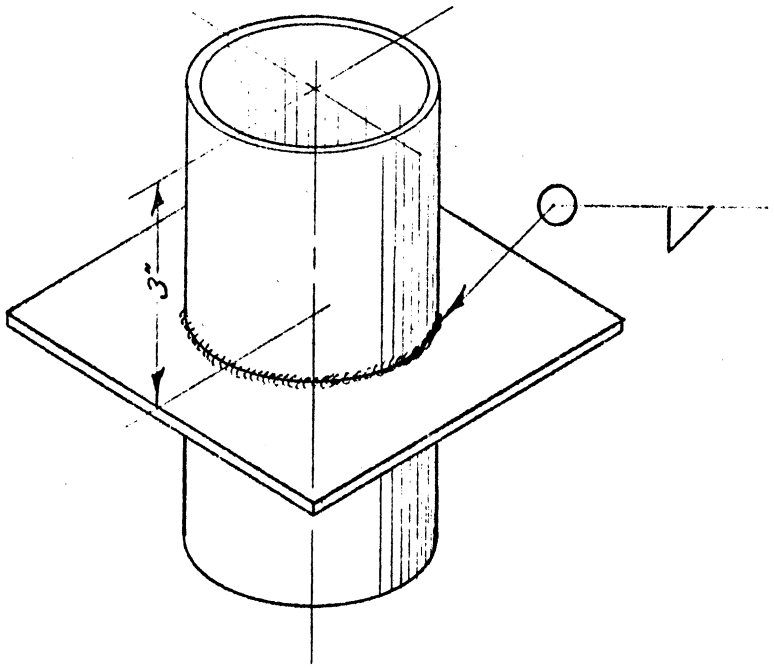
S - SAMPLE

PLATE 9

WELDERS' TEST

HELIARC WELDER - CLASS 3

FILLET WELD TEST



MATERIAL

1 - PIPE 3" x 6", Sch 40, S.S.
1 - SHEET 5" x 5" x 10 Ga, S.S.

TESTS

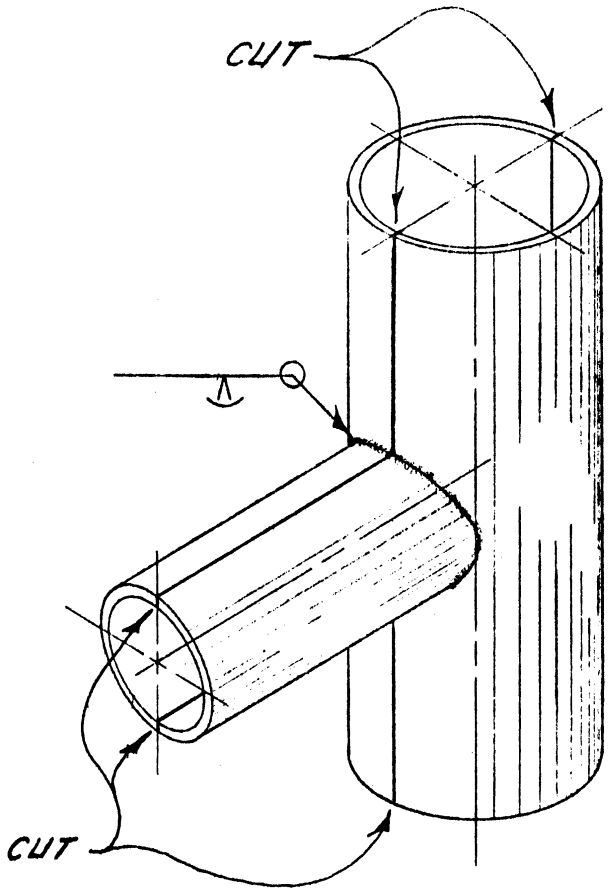
VISUAL

PLATE 10

WELDERS' TEST

HELIARC WELDER - CLASS 2

SADDLE WELD TEST



MATERIAL

1-PIPE 5" x 12", Sch. 40, S.S.
1-PIPE 3" x 6", Sch. 40, S.S.

TESTS

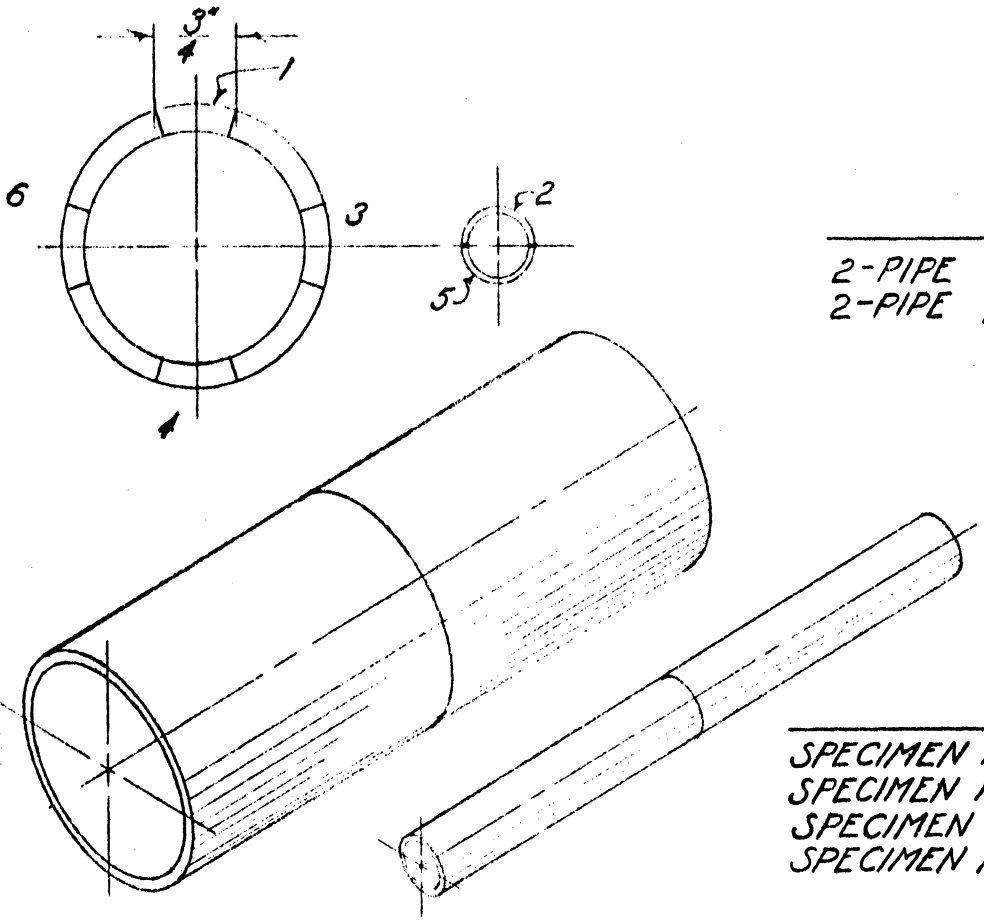
ONE HALF - NITRIC ACID ETCH

PLATE II

WELDERS' TEST

HELIARC WELDER - CLASS I

BUTT WELD TEST



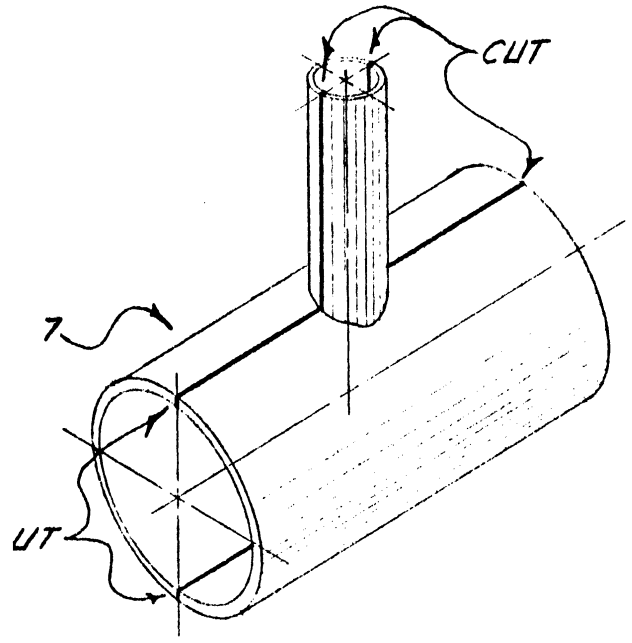
MATERIAL

2 - PIPE 2" x 6", Sch 40, S.S.
2 - PIPE ½" x 6", Sch 40, S.S.

TESTS

SPECIMEN No. 1, 2	NITRIC ACID ETCH
SPECIMEN No. 3	ROOT BEND
SPECIMEN No. 4, 5	RADIOGRAPH
SPECIMEN No. 6	CORROSION TEST

SADDLE WELD TEST



MATERIAL

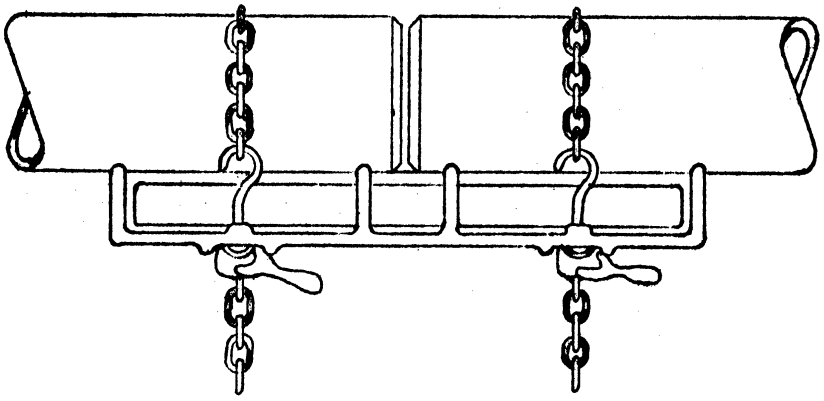
1 - PIPE 2" x 8", Sch. 40, S.S.
1 - PIPE ½" x 4", Sch 40, S.S.

TEST

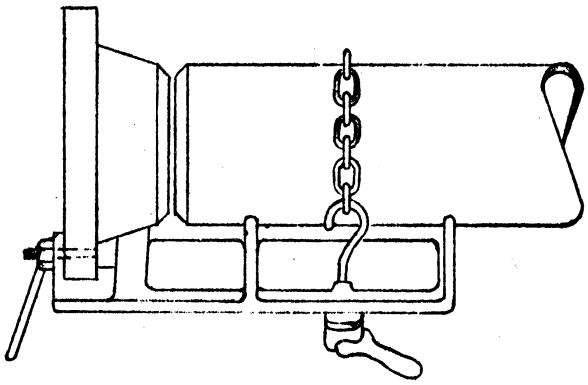
SPECIMEN No. 7 NITRIC ACID ETCH

PLATE 12

PIPE AND FLANGE CLAMPS
TYPICAL



PIPE CLAMP



FLANGE CLAMP

PLATE 13

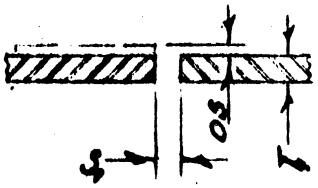
JOINT DETAILS

PREPARATION AND FITTING UP

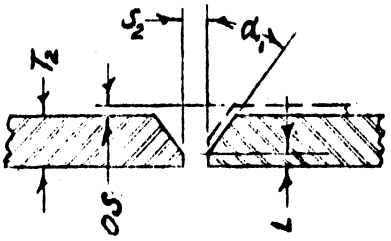
DIMENSIONS FOR BUTT WELD JOINTS

MATERIAL	SHAPE	T_1 MAX	S_1 MAX	T_2 MAX	T_2 MIN	α_1	$\angle$	S_2 MAX	T_3 MIN	α_2	OS OFFSET
CARBON STEEL	FLATS, SHAPES	3/32"	3/32"	3/8"	1/16"	$37\frac{1}{2}° \pm 2\frac{1}{2}°$	1/16±1/32	3/32"	1/4"	20°	1/4T
CARBON STEEL	PIPE	3/32"	3/32"	3/8"	1/16"	$37\frac{1}{2}° \pm 2\frac{1}{2}°$	1/16±1/32	3/32"	1/4"	20°	1/4T
SS (ARC)	FLATS, SHAPES	3/32"	3/32"	3/8"	1/16"	$37\frac{1}{2}° \pm 2\frac{1}{2}°$	3/32 +0 -1/32	3/32"	1/4"	20°	1/4T
SS (ARC)	PIPE (NOTE 1)	3/32"	3/32 +0 -1/32	3/8"	1/16	30°	3/32 +0 -1/32	3/32 +0 -1/32	1/4"	20°	1/5T
SS (HELIARC)	ALL SHAPES	1/16"	0"	3/8"	1/16"	$22\frac{1}{2}°$	1/16 +1/64 -0	0"	1/4"	15°	NOTE 2

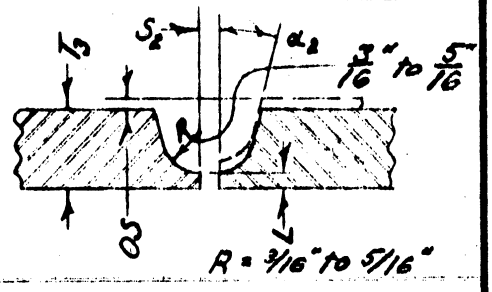
SQUARE BUTT



VEE GROVE

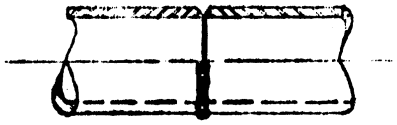


"U" GROVE

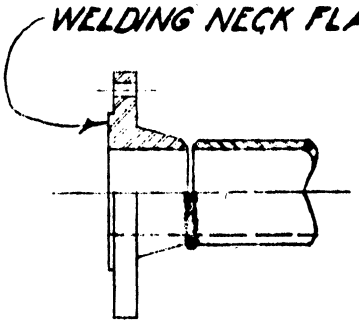


NOTE:

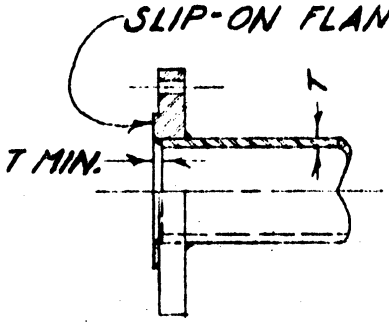
1. 2" SCH 40 OR SMALLER.
2. 1/16" OR 1/5T, WHICHEVER IS LEAST.



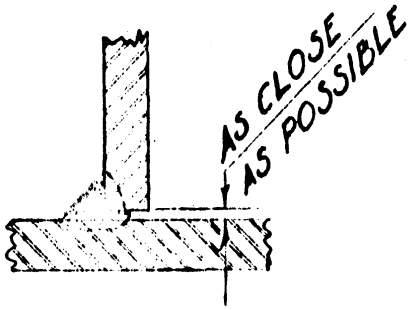
BUTT JOINT



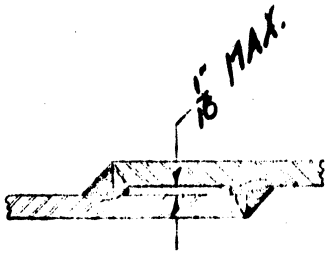
BUTT JOINT



FILLET WELD



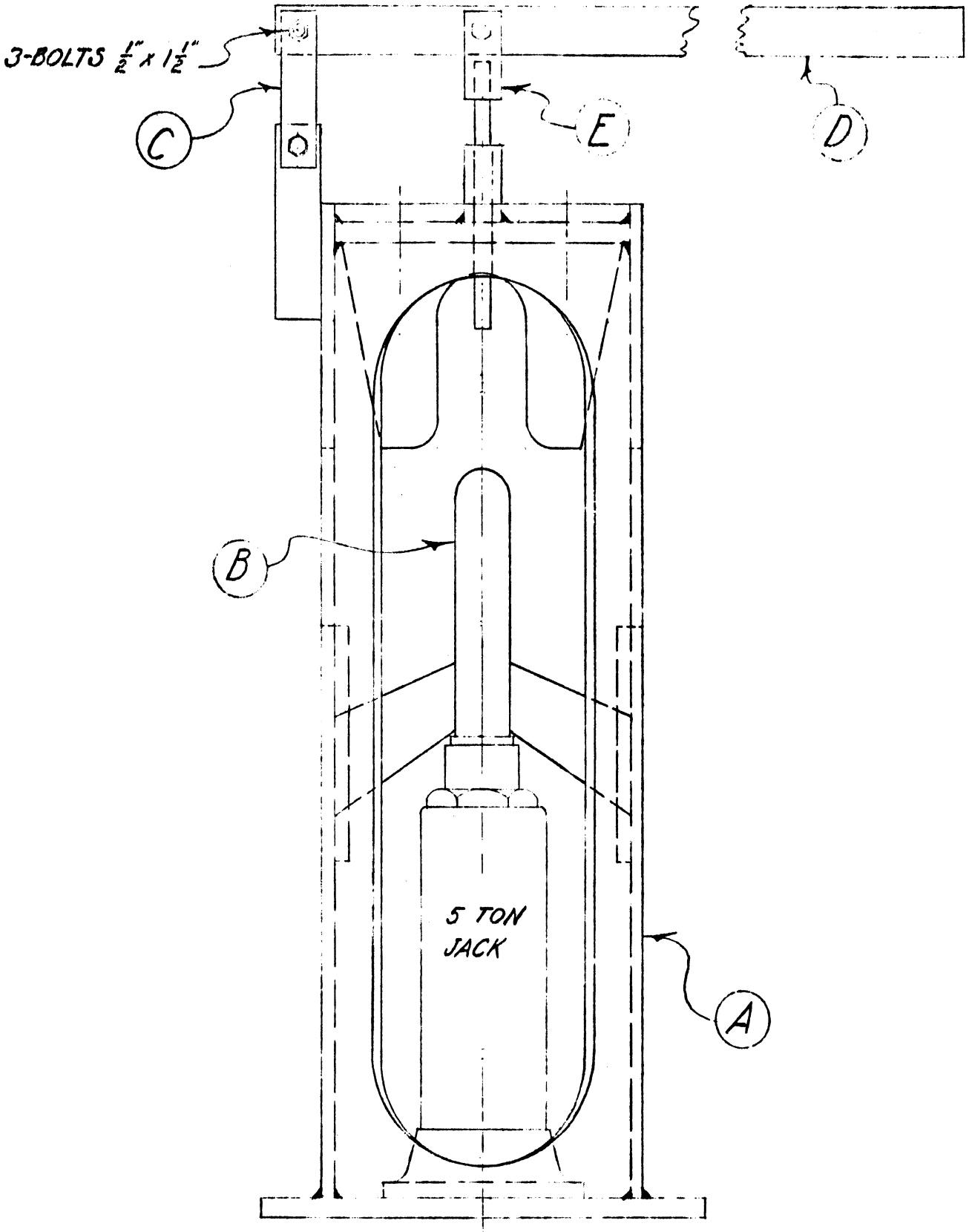
FILLET WELD



LAP JOINT

PLATE 14-A

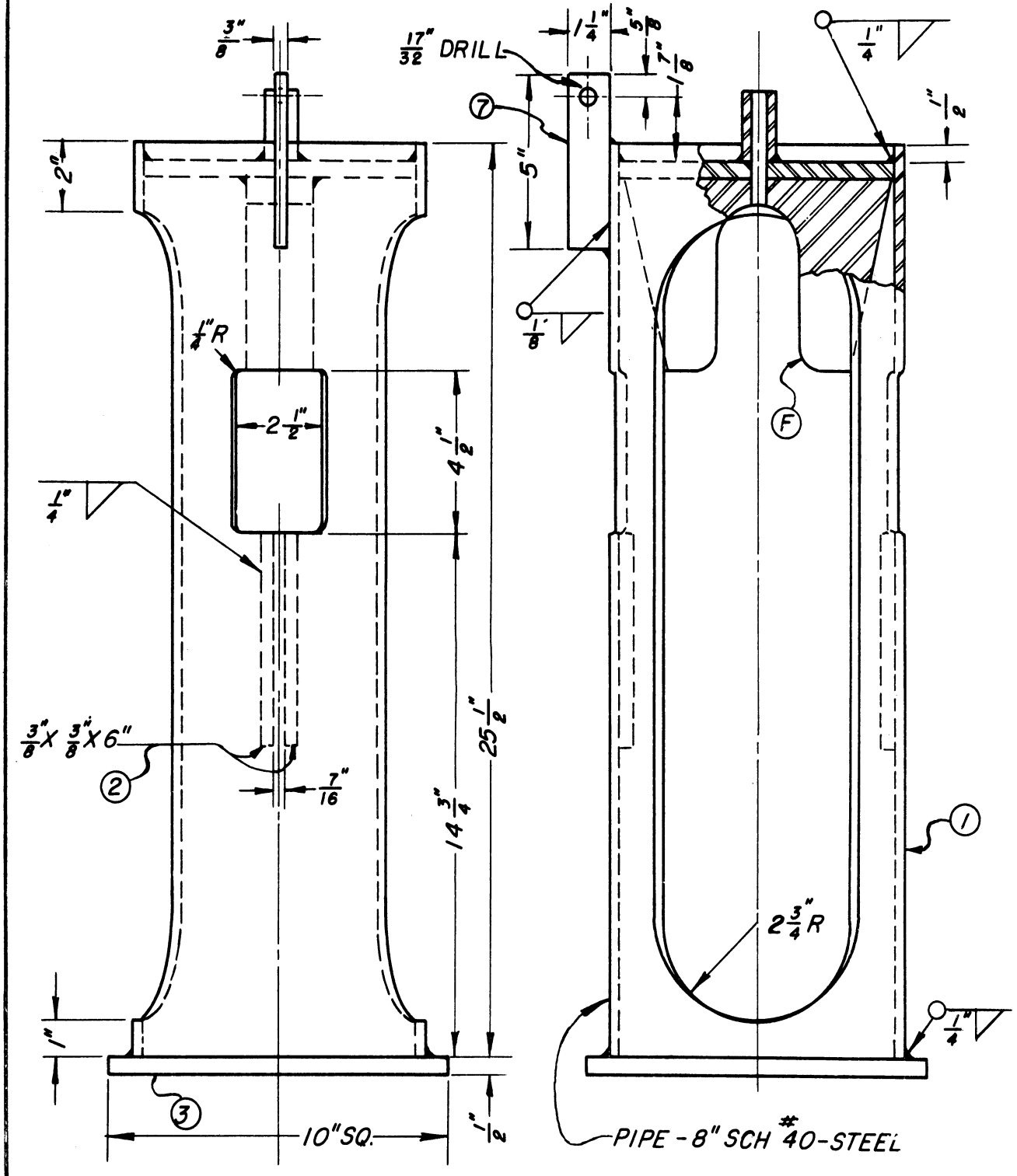
TEST JIG - GUIDED BEND TEST



NOTE: DIMENSIONS MARKED (*) ON PLATE 15-C ARE FOR TEST SPECIMENS 3/8" THICK. FOR OTHER THICKNESSES, CALCULATE FROM TABLE BELOW:

1 1/2"	3/4"	2 3/8"	1 3/16"
4 T	2 T	6 T + 1/8"	3 T + 1/16"

PLATE 14-B
TEST JIG - GUIDED BEND TEST

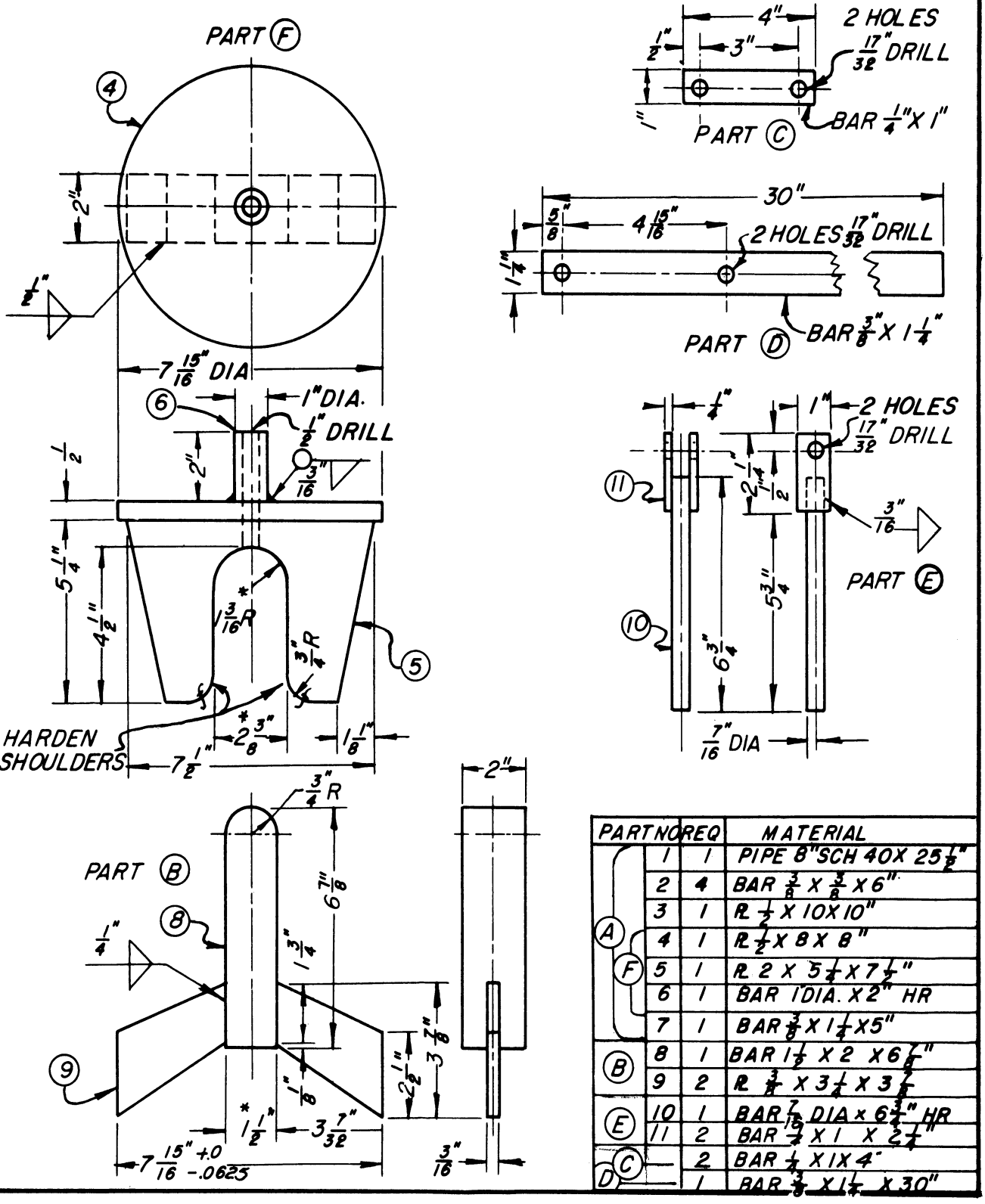


PART (A)

PLATE 14-C

TEST JIG - GUIDED BEND TEST

DETAILS & B.M.



PART	NO	REQ	MATERIAL
A F	1	1	PIPE 8" SCH 40 X 25 1/2"
	2	4	BAR 3/8 X 3/8 X 6"
	3	1	R 1/2 X 10 X 10"
	4	1	R 1/2 X 8 X 8"
	5	1	R 2 X 5 1/4 X 7 1/2"
	6	1	BAR 1" DIA. X 2" HR
	7	1	BAR 3/8 X 1 1/4 X 5"
B	8	1	BAR 1 1/2 X 2 X 6 7/8"
	9	2	R 3/8 X 3 1/4 X 3 7/8
E	10	1	BAR 7/16 DIA x 6 3/4" HR
	11	2	BAR 1/4 X 1 X 2 1/4"
C		2	BAR 1/4 X 1 X 4"
D		1	BAR 3/8 X 1 1/4 X 30"

TABLE I

AMPERAGE Vs. ELECTRODE SIZE

THIS TABLE IS TO BE USED AS A GUIDE ONLY.
IT IS NOT INTENDED TO REPLACE THE SOUND JUDGEMENT OF THE WELDER.

ROD DIA	CARBON STEEL DC	STAINLESS STEEL DC	MONEL 130 X DC	NICKEL 131 DC	INCONEL 132 DC	INCONEL 132 AC
ARC WELDING						
1/16			25-40	35-55	30-40	NR
3/32		35-80	45-60	65-85	35-50	NR
1/8		60-100	60-95	95-120	80-100	90-110
5/32		80-150	80-150	120-160	110-130	130-150
3/16		105-165	140-190	170-210	130-150	150-170
1/4			170-260	NR	NR	NR
HELIARC WELDING						
1/16		80-120				
3/32		120-150				
1/8		200-275				
3/16		275-375				
1/4		350-475				

NR - NOT RECOMMENDED

TABLE 2
FILLER ROD SPECS.

	BASE MATERIAL SPEC. NO.	METALLIC ARC ELECTRODE	HELIARC WIRE OR ROD
STAINLESS STEEL	AISI 302		304 WIRE
	AISI 304 ELC*	E 347-15	
	AISI 304	E-308-15	304 WIRE
	AISI 309 SCB	25-12 SCB OR 309 SCB **	309 SCB WIRE
	AISI 347	E-347-15	347 WIRE
NICKEL ALLOYS	MONEL	130 MONEL	60 MONEL
	326 MONEL	130 MONEL	43 MONEL
	K MONEL	134 K MONEL	64 K MONEL
	NICKEL	131 NICKEL	61 NICKEL
	LOW CARBON NICKEL	131 NICKEL	61 NICKEL
	INCONEL	132 INCONEL	62 INCONEL
	INCONEL X	139 INCONEL X	69 INCONEL X
	INCONEL W	139 INCONEL X	69 INCONEL X
	NIMONIC 75	142 80/20 NICKEL-CHROMIUM	62 INCONEL
	INCOLOY	132 INCONEL	62 INCONEL

* 0.03% CARBON MAXIMUM

* * WELD METAL ANALYSIS AISI TYPE 309 MODIFIED AS FOLLOWS:

0.08% CARBON MAX.

10 x C% CB MINIMUM

1.0% CB MAXIMUM

TABLE 3

HELIARC WELDING

1. PRINCIPLE WELDABLE TYPES OF STAINLESS STEELS

AUSTENITIC - (Cr - Ni)

	% C	% Cr	% Ni	% Others	Rod to Use
Type 301	0.08-0.20	17.0	7.0	--	OXWELD No. 28 or 304*
Type 302	0.08-0.20	18.0	8.0	--	OXWELD No. 28 or 304*
Type 304	0.08 max.	18.5	8.5	--	OXWELD No. 28 or 304*
Types 316	0.10 max.	17.0	12.0	Mo 2.5	OXWELD No. 28 or
317	0.10 max.	17.0	14.0	Mo 3.5	Types 316 and 317
Types 347	0.10 max.	18.5	10.0	Cb 10 x C	OXWELD No. 28*
321	0.10 max.	18.5	10.0	Ti 4 x C	OXWELD No. 28
Type 308	0.08 max.	20.0	11.0	Mn 2.00 max.	OXWELD No. 28, 308
Type 309	0.20 max.	24.0	13.0	--	Type 309, OXWELD No. 28
Type 310	0.25 max.	25.0	20.0	--	Type 310, OXWELD No. 28
Type 318	0.10 max.	17.0	12.0	Mo 2.5 Cb 10 x C	Type 318

*No. 309 rod should be used for giving high impact resistance at low temperatures - otherwise use rods listed.

FERRITIC - (Straight Cr)

	% C	% Cr	% Others	Rod to Use
Type 430	0.12 max.	14.0-18.0	--	310,* 309 U.M.* - 430
Type 446	0.35 max.	26.0	--	310, 309 U.M. - 446

*These rods give ductile weld metal.

MARTENSITIC - (Straight Cr)

	% C	% Cr	% Others	Rod to Use
Type 410	0.15 max.	12.0	--	310, 309 U.M. 410 or 430
Type 416	0.15 max.	13.0	P, S, or Se 0.07 min. - Zr or Mo 0.60 max.	310, 309 U.M. 416, 410, 430
Type 501	0.10	5.0	--	310, 309 U.M. 502
Type 502	0.10 max.	5.0	--	310, 309 U.M. 502

2. SPECIAL PRECAUTIONS

AUSTENITIC TYPE (Cr - Ni)

1. Occasional hot tearing:
   Cause - Improper joint design, sequence of welding, or jigging.
   Correction - Use proper welding current and sequence of welding.
   Change joint design.

TABLE 3 (Cont'd.)

AUSTENITIC TYPE (Cr - Ni) (Cont'd.)

2. Decreased ductility:
Correction - Use lower current and/or multi-pass technique in which narrow stringer beads can be made at high speed and high current.

3. Decreased corrosion resistance near weld:
Cause - Heat effect of welding causes carbide precipitation.
Correction - Use Cb or Ti stabilized base metal (such as Type 347) and Cb stabilized rod; or heat treat entire assembly at 1900 deg. F. and cool rapidly after welding.

FERRITIC TYPE (Straight Cr, 14% and above)

1. Lower Cr grades may be air hardening. C and Cr contents must be balanced. Higher C requires higher Cr to maintain non-hardening structure.

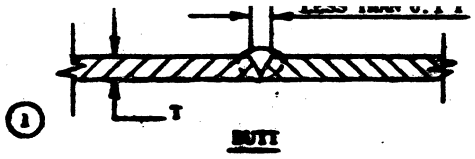
2. Grain size increases with Cr content:
Good combination of properties with 15-16% Cr- good impact resistance. No air hardening occurs when C is below 0.10%.

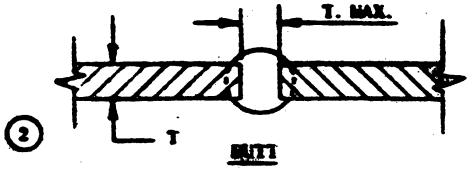
3. To increase toughness:
Heat treatment followed by annealing.

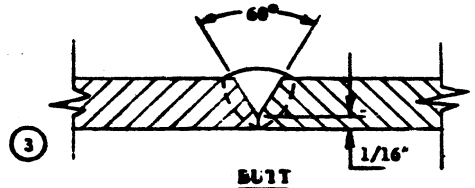
4. To prevent possible cracking if C is high:
Preheat to about 400 deg. F.

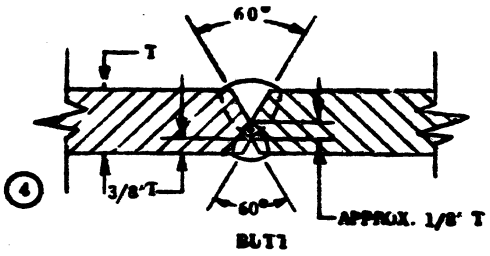
MARTENSITIC TYPE (Straight Cr)

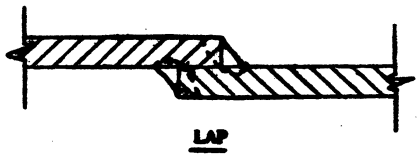
1. Air hardening:
Preheat to 400 to 500 deg. F. to avoid cracking. Follow by annealing to avoid excessive hardness and cracking. Follow recommendations of manufacturer.

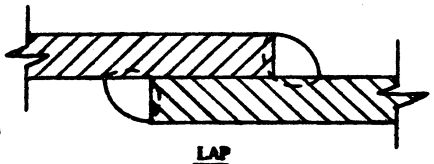


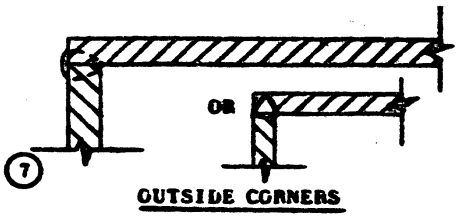


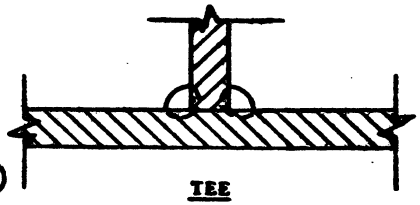


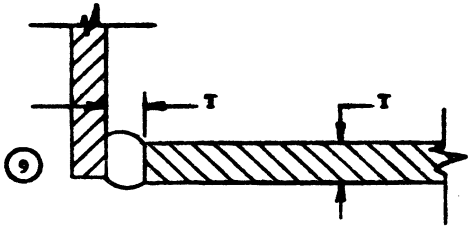


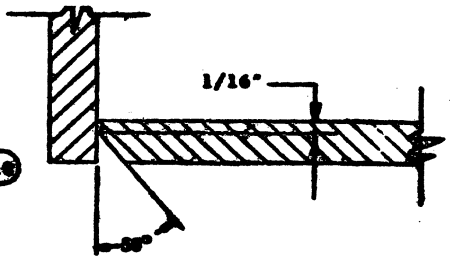












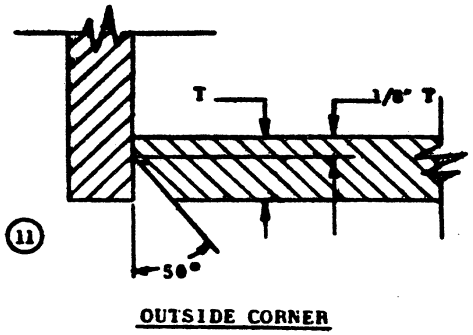


TABLE 4
HELIARC WELDING

"HELIARC" HAND-WELDING OF STAINLESS STEEL*

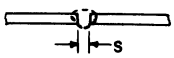
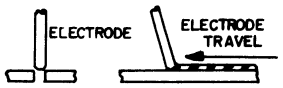
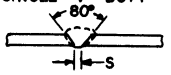
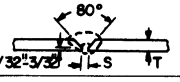
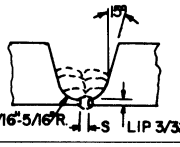
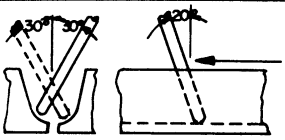
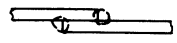
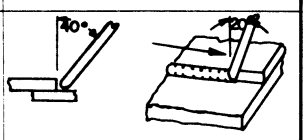
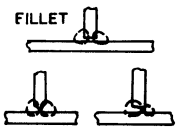
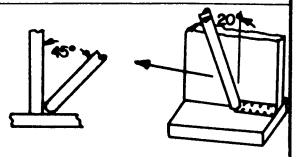
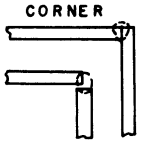
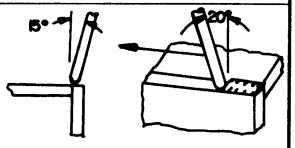
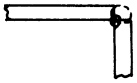
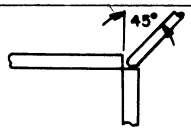
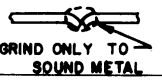
Thickness In.	Type of Weld	Welding Current: Characteristics	Welding Current: Amperes: Flat	Welding Current: Amperes: Vertical	Welding Current: Amperes: Overhead	Electrode Diameter In.	** Welding Speed I.P.M.	Welding Rod: Material Name No.	Welding Rod: Size In.	Gas Cup or Nozzle: HW-10 and HW-4 Torches: Ceramic Max. Rating 250 Amps. AC—DC: HW-10	Gas Cup or Nozzle: HW-10 and HW-4 Torches: Ceramic Max. Rating 250 Amps. AC—DC: HW-4	Gas Cup or Nozzle: HW-10 and HW-4 Torches: Metal Max. Rating 300 Amps. AC—DC: HW-10	Gas Cup or Nozzle: HW-10 and HW-4 Torches: Metal Max. Rating 300 Amps. AC—DC: HW-4	Gas Cup or Nozzle: HW-5 Torch: Metal Max. Rating 500 Amps AC 500 Amps DC	Argon Flow at Recommended 20 psi: L.P.M.	Argon Flow at Recommended 20 psi: C.F.H.	Remarks
1/16"	1,2 Butt	Straight Polarity — Direct Current	80-100	70- 90 up	70-90	1/16"	12	For welding rod to use, refer to TABLE 3 "Principal Weldable Types of Stainless Steel."	1/16"	4 or 5	6	4 or 5	—	—	5	11	
	5,6 Lap		100-120	80-100 up	80-100	1/16"	10		1/16"	4 or 5	6	4 or 5	—	—	5	11	
	7 Corner		80-100	70- 90 up	70-90	1/16"	12		1/16"	4 or 5	6	4 or 5	—	—	5	11	
	8,9 Fillet		90-110	80-100 up	80-100	1/16"	10		1/16"	4 or 5	6	4 or 5	—	—	5	11	
3/32"	1,2 Butt		100-120	90-110 up	90-110	1/16"	12		1/16" or 3/32"	4 or 5	6	4 or 5	—	—	5	11	
	5,6 Lap		110-130	100-120 up	100-120	1/16"	10		1/16" or 3/32"	4 or 5	6	4 or 5	—	—	5	11	
	7 Corner		100-120	90-110 up	90-110	1/16"	12		1/16" or 3/32"	4 or 5	6	4 or 5	—	—	5	11	
	8,9 Fillet		110-130	100-120 up	100-120	1/16"	10		1/16" or 3/32"	4 or 5	6	4 or 5	—	—	5	11	
1/8"	1, 2 Butt		120-140	110-130 up	105-125	1/16"	12		3/32"	4 or 5	6 or 7	4 or 5	—	—	5	11	
	5,6 Lap		130-150	120-140 up	120-140	1/16"	10		3/32"	4 or 5	6 or 7	4 or 5	—	—	5	11	
	7 Corner		120-140	110-130 up	115-135	1/16"	12		3/32"	4 or 5	6 or 7	4 or 5	—	—	5	11	
	8,9 Fillet		130-150	115-135 up	120-140	1/16"	10		3/32"	4 or 5	6 or 7	4 or 5	—	—	5	11	
3/16"	1,2 Butt		200-250	150-200 up	150-200	3/32"	10		1/8"	6 or 7	8	5 or 6	6 or 8	or 8	6	13	
	6 Lap		225-275	175-225 up	175-225	3/32",1/8"	8		1/8"	6,7,8	8	6,7,8	6 or 8	or 8	6	13	
	7 Corner		200-250	150-200 up	150-200	3/32"	10		1/8"	6 or 7	8	5 or 6	6 or 8	or 8	6	13	
	8,9 Fillet		225-275	175-225 up	175-225	3/32",1/8"	8		1/8"	6,7,8	8	6,7,8	6 or 8	or 8	6	13	
1/4"	2,3 Butt		275-350	200-250 up	200-250	1/8"	—		3/16"	—	—	—	—	8	6	13	One or Two Passes
	6 Lap		300-375	225-275 up	225-275	1/8"	—		3/16"	—	—	—	—	8	6	13	One or Two Passes
	7 Corner		275-350	200-250 up	200-250	1/8"	—		3/16"	—	—	—	—	8	6	13	One Pass
	8,10 Fillet		300-375	225-275 up	225-275	1/8"	—		3/16"	—	—	—	—	8	6	13	
1/2"	3,4 Butt		350-450	225-275 up	225-275	1/8",3/16"	—		1/4"	—	—	—	—	8 or 10	7	15	Two or Three Passes
	6 Lap		375-475	230-280 up	230-280	1/8",3/16"	—		1/4"	—	—	—	—	8 or 10	7	15	Three Passes
	8,10 Corner		375-475	230-280 up	230-280	1/8",3/16"	—		1/4"	—	—	—	—	8 or 10	7	15	Three Passes

*Conditions very similar for HASTELLOY B & C and other similar alloys.

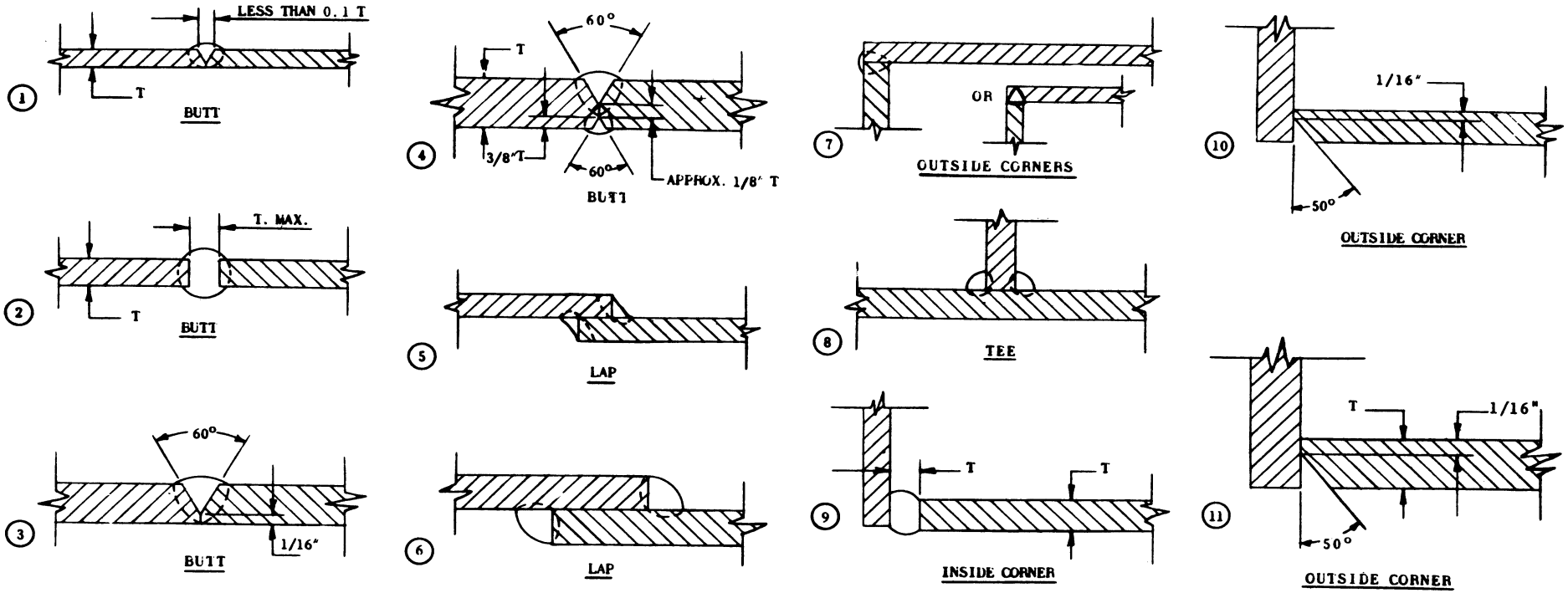
**Welding speed for flat position.

TABLE 5

ELECTRODE POSITIONS AND ARC WELDING DATA FOR MONEL, NICKEL, AND INCONEL

JOINT TYPE 100% PENETRATION IS ASSUMED	MINIMUM AND MAXIMUM GAUGES (U.S.S.) FOR VARIOUS POSITIONS		ROOT SPACING "S" BETWEEN PLATES IN COLUMN 1		JOINT BACKING- (COPPER BARS ARE PREFERRED)	TACK WELDS	ELECTRODE DIAMETER		NO. OF PASSES REQUIRED TO COMPLETE THE JOINT	ELECTRODE POSITIONS FOR DOWNHAND WELDING END AND SIDE VIEWS
	MINIMUM	MAXIMUM	FOR MIN. GA.	FOR MAX. GA.			FOR MIN. GA.	FOR MAX. GAUGE		
COLUMN 1	2	3	4		5	6	7	8	9	10
SQUARE BUTT 	(F) .037" (20 GA.) (V) .062" (16 GA.) (O) .050" (18 GA.)	.125" (11 GA.) .125" (11 GA.) .125" (11 GA.)	0 0 0	1/16" 1/16" 3/32"	BACKING IS NECESSARY FOR GAUGES .050" (18 GA. U.S.S.) AND THINNER — IF DESIGN PERMITS, BACKING SHOULD BE PROVIDED FOR GAUGES .062" (16 GA U.S.S.) TO .093" (13 GA. U.S.S.)	1/8" LONG ON 3"-4" CENTERS	.075" .075" 3/32"	1/8" 1/8" 1/8"	1 1 1	
SINGLE "V" BUTT  OR SINGLE "V" (WITH LIP) BUTT 	(F) 5/32" (9GA.) (V) 5/32" (9GA.) (O) 5/32" (9GA.)	5/16" 3/8" 5/16"	1/16" 1/16" 1/16"	3/32" 3/32" 3/32"		1/4" - 1/2" LONG ON 6" CENTERS	1/8" 1/8" 1/8"	5/32" 5/32" 5/32"	1 FOR 5/32" TO 3/16" PLATE 2 FOR 1/4" PLATE 3 FOR 3/8" PLATE 3 OR 4 FOR 7/16" & 1/2" PLATE	
	(F) 5/32" (9GA.) (V) 3/16" (7 GA.)	1/2" 7/16"	1/16" 1/16"	1/8" 1/8"		1/4"-1/2" LONG ON 6" CENTERS	1/8" 1/8"	3/16" 3/16"		
"U" GROOVE BUTT 	(F) 1/2" (V) 1/2"	NO MAX. NO MAX.	1/16" 1/16"	3/32" 3/32"		1" LONG ON 8" CENTERS	1/8" 1/8"	5/32"&3/16" 5/32"&3/16"	DEPENDS ON PLATE THICKNESS	
LAP 	(F) .037" (20 GA.) (V) .062" (16 GA.) (O) .062" (16 GA.)	NO MAX. NO MAX. NO MAX.	NONE NONE NONE			1/4" LONG ON 6" CENTERS	.075" .075" .075"	5/32-3/16" 5/32-3/16" 5/32-3/16"	1 OR MORE	
FILLET 	(F) .062" (16 GA.) (V) .062" (16 GA.) (O) .062" (16 GA.)	NO MAX. NO MAX. NO MAX.	NONE NONE NONE			1/4"-1/2" LONG ON 6" CENTERS	3/32" 3/32" 3/32"	5/32"-3/16" 5/32"-3/16" 5/32"-3/16"	1 OR MORE	
CORNER 	(F) .050" (18 GA.) (V) .062" (16 GA.) (O) .062" (16 GA.)	1/8" (11GA) 1/8" (11GA.) 1/8" (11 GA.)	NONE NONE NONE			1/4" LONG ON 4" CENTERS	.075" .075" .075"	1/8" 1/8" 1/8"	1 1 1	
CORNER 	(F) 3/32" (13GA) (V) 3/32" (13 GA) (O) 3/32" (13GA.)	NO MAX. NO MAX. NO MAX.	NONE NONE NONE			1/4" LONG ON 4"-8" CENTERS	1/8" 1/8" 1/8"	5/32"-3/16" 5/32"-3/16" 5/32"-3/16"	DEPENDS ON PLATE THICKNESS	
	(F) .037" (20GA.)	.062" (16 GA)	NONE			1/4" LONG ON 4"-8" CENTERS	.075"	3/32"	1	SAME AS FOR SQUARE BUTT (AT TOP OF PAGE)
 GRIND ONLY TO SOUND METAL	(F) .031" (22 GA.)	.050" (18GA.)	NONE			1/4" LONG ON 4"-8" CENTERS	.075"	3/32"	1	SAME AS FOR SQUARE BUTT (AT TOP OF PAGE)

(F)=FLAT POSITION (V)=VERTICAL POSITION (O)=OVERHEAD POSITION



"HELIARC" WELDING OF DEOXIDIZED COPPER

THICKNESS IN.	TYPE OF WELD	WELDING CURRENT AMPS TYPE	WELDING CURRENT AMPS FLAT	ELECTRODE DIA. IN.	WELDING SPEED I.P.M.	WELDING ROD MATERIAL NAME NO. ⊕	WELDING ROD SIZE IN.	GAS CUPS HW-4 TORCH CERAMIC MAX. RATING 250 AMPS AC 250 AMPS DC	GAS CUPS HW-4 TORCH WATER-COOLED MAX. RATING 300 AMPS AC 300 AMPS DC	GAS CUPS HW-5 TORCH WATER-COOLED MAX. RATING 500 AMPS AC 500 AMPS DC	ARGON FLOW AT RECOMMENDED 20 psi L.P.M.	ARGON FLOW AT RECOMMENDED 20 psi C.F.H.	REMARKS
1/16"	1,2 Butt	DIRECT CURRENT - STRAIGHT POLARITY	110-140	1/16"	12	Copper	1/16"	7			7	15	One Pass
	5,6 Lap		130-150	1/16"	10	Copper	1/16"	7			7	15	One Pass
	7 Corner		110-140	1/16"	12	Copper	1/16"	7			7	15	One Pass
	8 Fillet		130-150	1/16"	10	Copper	1/16"	7			7	15	One Pass
1/8"	1,2 Butt		175-225	3/32"	11	Copper	3/32" or 1/8"	8	8		7	15	One Pass
	6 Lap		200-250	3/32"	9	Copper	3/32" or 1/8"	8	8		7	15	One Pass
	7 Corner		175-225	3/32"	11	Copper	3/32" or 1/8"	8	8		7	15	One Pass
	8,9 Fillet		200-250	3/32"	9	Copper	3/32" or 1/8"	8	8		7	15	One Pass
3/16"	1,2 Butt		250-300	1/8"	10	Copper	1/8"			8	7	15	One Pass; Preheat to 500°F.
	6 Lap		275-325	1/8"	8	Copper	1/8"			8	7	15	One Pass; Preheat to 500°F.
	7 Corner		250-300	1/8"	10	Copper	1/8"			8	7	15	One Pass; Preheat to 500°F.
	8,10 Fillet		275-325	1/8"	8	Copper	1/8"			8	7	15	One Pass; Preheat to 500°F.
1/4"	3 Butt		300-350	1/8"	9	Copper	1/8"			8	7	15	One Pass; Preheat to 600°F.
	6 Lap		325-375	1/8"	7	Copper	1/8"			8	7	15	One Pass; Preheat to 600°F.
	7 Corner		300-350	1/8"	9	Copper	1/8"			8	7	15	One Pass; Preheat to 600°F.
	8,10 Fillet		325-375	1/8"	7	Copper	1/8"			8	7	15	One Pass; Preheat to 600°F.
3/8"	3 Butt		375-425	3/16"		Copper	3/16"			10	8	17	Two Passes; Preheat to 800°F.
	6 Lap		400-450	3/16"		Copper	3/16"			10	8	17	Three Passes; Preheat to 800°F.
	7 Corner		375-425	3/16"		Copper	3/16"			10	8	17	Two Passes; Preheat to 800° F.
	8,10 Fillet		400-450	3/16"		Copper	3/16"			10	8	17	Three Passes; Preheat to 800°F.
1/2"	4 Butt		500-700	3/16", 1/4"		Copper	1/4"			10	8	17	Three Passes; Preheat 900° to 1200°F.

⊕ *Anaconda No. 372 Copper Welding Rod*

TABLE 6

TABLE 7

OXY-ACETYLENE WELDING OF DEOXIDIZED COPPER

SUMMARY OF PREPARATIONS FOR FLAT POSITION FOREHAND WELDING*

PLATE THICK-NESS Inches	TYPE JOINT	BEVEL ANGLE Degrees	ROOT FACE Inches	ROOT SPACE (1) Inches	NO. LAYERS (2)	FILLER ROD Diam. Inches	FILLER ROD Lbs./ft. required (approx.)
1/8	Square Butt	--	--	1/16	2	1/8	.169
3/16	Square Butt	--	--	3/32-1/8	2	5/32	.317
1/4	Single Vee	45	1/16-3/32	1/8	2	3/16	.453
3/8	Single Vee	45	3/32-1/8	1/8	2	1/4	.908
1/2	Single Vee	45	1/8-5/32	1/8	3	5/16	1.449
5/8	Single Vee	45	1/8-5/32	1/8	3	5/16	2.292
3/4	Single Vee	45	1/8-3/16	1/8	3 or 4	5/16	3.078

(1) Root space should be tapered 3/16" ft. to allow for contraction of metal in initial layer.

(2) Number of layers shown include layer on reverse side after chip-out.

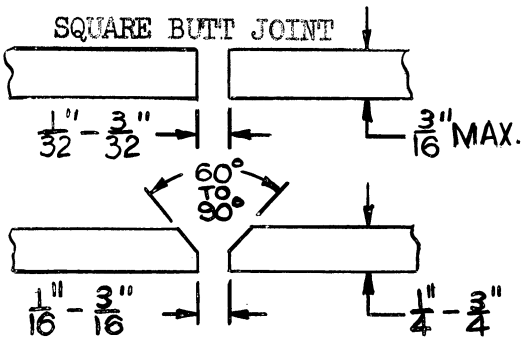
* For backhand welding, use 30° bevel angle and 10-12° inclination.

SUMMARY OF PREPARATIONS FOR DOUBLE VERTICAL WELDING

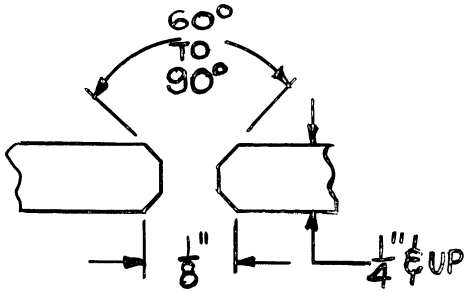
PLATE THICKNESS Inches	SQUARE BUTT (1) Diam. Inches	SQUARE BUTT (1) FILLER ROD Lbs./ft. required (approx.) (2)	DOUBLE VEE BEVEL ANGLE Degrees	DOUBLE VEE ROOT FACE Inches	DOUBLE VEE Diam. Inches	DOUBLE VEE FILLER ROD Lbs./ft. req'd. (approx.) (2)
1/8	1/8	.150	--	--	--	--
3/16	1/8	.180	--	--	--	--
1/4	5/32	.240	--	--	--	--
3/8	3/16	.360	45	1/16	3/16	.490
1/2	3/16	.480	45	1/8	1/4	.756
5/8	1/4	.600	45	1/8	1/4	1.085
3/4	--	--	45	1/8	1/4	1.470

(1) No edge preparation.

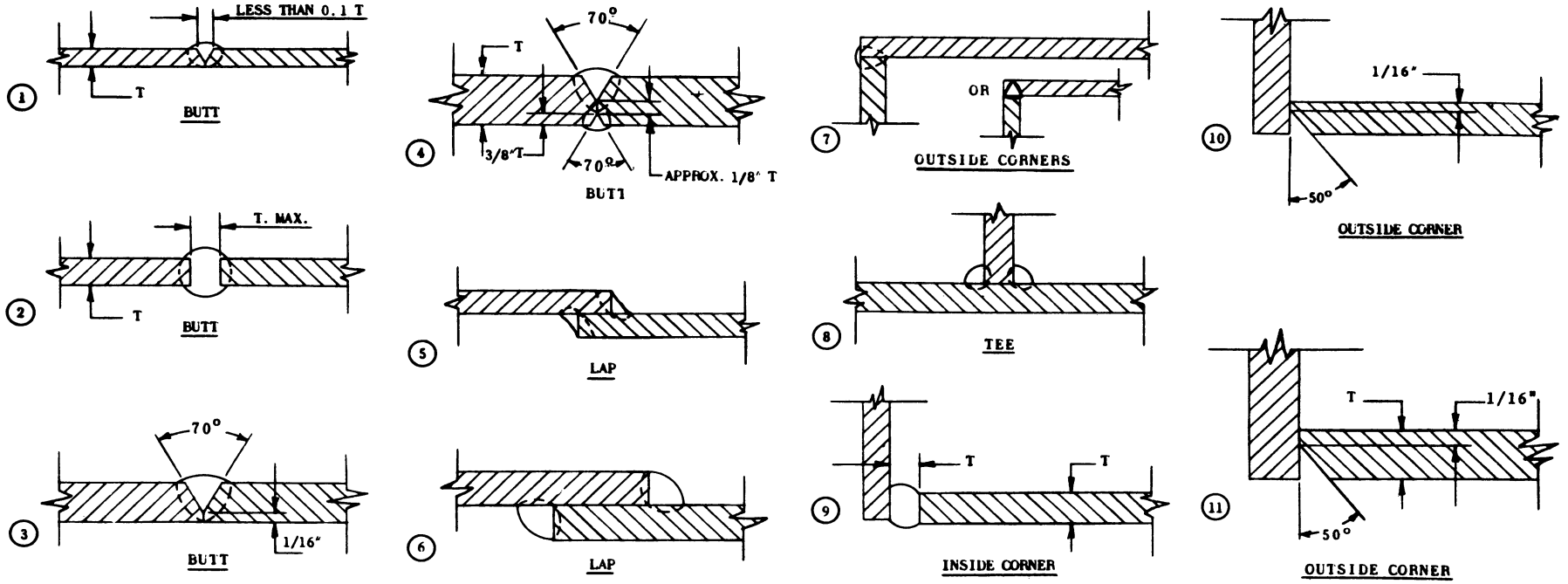
(2) For joints set up with no root space.



SINGLE VEE JOINT



DOUBLE VEE JOINT



"HELIARC" WELDING OF SILICON BRONZE

THICK-NESS IN.	TYPE OF WELD	WELDING CURRENT TYPE	AMPERES FLAT	AMPERES VERTICAL	AMPERES OVERHEAD	ELECTRODE DIA. IN.	* WELDING SPEED I.P.M.	WELDING ROD MATERIAL NAME NO. ⊕	WELDING ROD SIZE IN.	GAS CUPS HW-4 TORCH CERAMIC MAX. RATING 250 AMPS AC 250 AMPS DC	GAS CUPS HW-4 TORCH WATER-COOLED MAX. RATING 300 AMPS AC 300 AMPS DC	GAS CUPS HW-5 TORCH WATER-COOLED MAX. RATING 500 AMPS AC 500 AMPS DC	ARGON FLOW AT RECOMMENDED 20 psi L.P.M.	ARGON FLOW AT RECOMMENDED 20 psi C.F.H.	REMARKS
1/16"	1,2 Butt	DIRECT CURRENT - STRAIGHT POLARITY	100-120	90-110 Up	90-110	1/16"	12	Everdur	1/16"	6	--	--	6	13	
	5,6 Lap		110-130	100-120 Up	100-120	1/16"	10	Everdur	1/16"	6	--	--	6	13	
	7 Corner		100-130	90-110 Up	90-110	1/16"	12	Everdur	1/16"	6	--	--	6	13	
	8,9 Fillet		110-130	100-120 Up	100-120	1/16"	10	Everdur	1/16"	6	--	--	6	13	
1/8"	1,2 Butt		130-150	120-140 Up	120-140	1/16"	12	Everdur	3/32"	7	--	--	7	15	
	5,6 Lap		140-160	130-150 Up	130-150	1/16",3/32"	10	Everdur	3/32"	7	--	--	7	15	
	7 Corner		130-150	120-140 Up	120-140	1/16"	12	Everdur	3/32"	7	--	--	7	15	
	8,9 Fillet		140-160	130-150 Up	130-150	1/16",3/32"	10	Everdur	3/32"	7	--	--	7	15	
3/16"	1,2 Butt		150-200	--	--	3/32"	--	Everdur	1/8"	8	8	--	8	17	
	5,6 Lap		175-225	--	--	3/32"	--	Everdur	1/8"	8	8	--	8	17	
	7 Corner		150-200	--	--	3/32"	--	Everdur	1/8"	8	8	--	8	17	
	8,9 Fillet		175-225	--	--	3/32"	--	Everdur	1/8"	8	8	--	8	17	
1/4"	1,2 Butt		150-200	--	--	3/32"	--	Everdur	1/8" or 3/16"	8	--	--	9	19	Three Passes
	3 Butt		250-300	--	--	1/8"	--	Everdur	1/8" or 3/16"	--	8	8	9	19	One Pass - Square Butt
	6 Lap		175-225	--	--	3/32"	--	Everdur	1/8" or 3/16"	--	8	--	9	19	Three Passes
	8,10 Fillet		175-225	--	--	3/32"	--	Everdur	1/8" or 3/16"	--	8	--	9	19	Three Passes
3/8"	3 Butt		230-280	--	--	1/8"	--	Everdur	1/8", 3/16"	--	--	8	9	19	Three or Four Passes
	6 Lap		250-300	--	--	1/8"	--	Everdur	1/8", 3/16"	--	--	8	9	19	Three Passes
	8,10 Fillet		230-280	--	--	1/8"	--	Everdur	1/8", 3/16"	--	--	8	9	19	Three Passes
1/2"	3 Butt		250-300	--	--	1/8"	--	Everdur	1/8", 3/16"	--	--	8	9	19	Four or Five Passes
	6 Lap		275-325	--	--	1/8"	--	Everdur	1/8", 3/16"	--	--	8	9	19	Six Passes
	8,10 Fillet		275-325	--	--	1/8"	--	Everdur	1/8", 3/16"	--	--	8	9	19	Seven Passes
3/4"	3,4 Butt		275-325	--	--	1/8"	--	Everdur	3/16"	--	--	8	9	19	Nine or Ten Passes
	6 Lap		300-350	--	--	1/8"	--	Everdur	3/16"	--	--	8	9	19	Twelve Passes
	8,11 Fillet		300-350	--	--	1/8"	--	Everdur	3/16"	--	--	8	9	19	Fourteen Passes
1"	3,4 Butt		300-350	--	--	1/8"	--	Everdur	3/16", 1/4"	--	--	8	9	19	Thirteen Passes
	6 Lap		325-350	--	--	1/8"	--	Everdur	3/16", 1/4"	--	--	8	9	19	Sixteen Passes
	8,11 Fillet		325-350	--	--	1/8"	--	Everdur	3/16", 1/4"	--	--	8	9	19	Twenty Passes

⊕ *OXWELD No. 26 Everdur Welding Rod.*

* *For welding in flat position.*

TABLE 8

TABLE 9

HELIARC WELDING OF ALUMINUM BRONZE

PLATE THICK in.	EDGE PREP.	WELDING CURRENT Amperes ACHF	ARGON FLOW at recommended 20 psi lpm	ARGON FLOW at recommended 20 psi chf	ELECTRODE DIAMETER in.	NUMBER OF PASSES
1/4	90° V, sharp nose	200	8	17	1/8	2
3/8	60° V, sharp nose	250	8	17	5/32	3
1/2	60° V, sharp nose	260	8	17	5/32	4

No flux required.

HELIARC WELDING OF SEVERAL COPPER ALLOYS

	TYPE OF WELDING CURRENT	FLUX	WELDING TECHNIQUE	ROD
Brass	DCSP over 0.050" ACHF under 0.050"	BRAZO*	Forehand	OXWELD No. 26*
Phosphor Bronze	DCSP	None	Forehand	OXWELD No. 26*
Leaded Bronzes	DCSP	None	Forehand	OXWELD No. 26*
Beryllium-Copper	ACHF	None	Forehand	Be-Cu

CARBON ARC WELDING OF DEOXIDIZED COPPER

THICKNESS BASE METAL Inches	TYPE JOINT	BEVEL ANGLE Degrees	ROOT FACE Inches	NUMBER OF LAYERS	Diameter Inches	Lbs. req'd./ft. of Seam	CARBON ELECTRODE Diameter Inches	WELDING CURRENT AND ARC LENGTH Amps.	Volts
1/16	Square Butt	--	--	1	1/8	.0453	1/4	120-140	20-25
1/8	Square Butt	--	--	1	3/16	.1023	5/16	200-220	30-35
3/16	Single Vee	45	1/16	1	1/4	.1818	3/8	260-300	35-40
1/4	Single Vee	45	1/16	1	5/16	.2833	1/2	400-440	40-50
5/16	Single Vee	45	1/16	1	3/8	.4086	1/2	420-460	45-50

*Or equivalent.

TABLE 10

COPPER ALLOY FILLER ROD SELECTION AND PREHEAT CHART

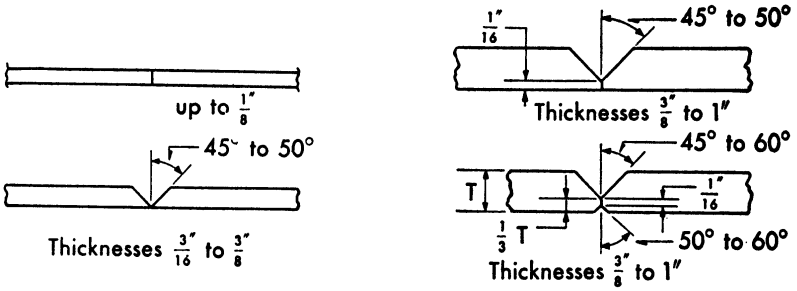
ALLOY →	LOW NICKEL STEEL	MANGANESE STEEL	TOOL STEEL	STAINLESS STEEL	CAST IRON	CARBON STEEL	COPPER-BERYLLIUM	COPPER-NICKEL	COPPER ALUMINUM	COPPER TIN	COPPER-SILICON	COPPER ZINC	COPPER
Copper	3G	3G	3G	3G	3G	3G	3G	5,3G	3,2G	3,2G	2G	3,2G	1,3,2G
Copper-zinc	3,4D	3,4D	3,4F	3,4D	3,4D	3,4D	3,4F	5,4D	3,4D	3,2D	3,2D	3,2,4D	
Copper-silicon	2,3,4A	2,3,4A	2,3,4F	2,3,4A	2,3,4C	2,3,4A	2,4F	2,5C	2,4A	3,2C	2A		
Copper-tin	3C	3C	3F	3C	3C	3C	3,2F	3,5C	3C	3C			
Copper-aluminum	4C	4C	4F	4C	4,3D	4C	4F	4,5C	4C				
Copper-nickel	5,4A	5,4A	5,4F	5,4A	5,4C	5,4A	4,5F	5A					
Copper-beryllium	4,3F	4,3F	4,3F	4,3F	3,4F	4,3F	6F						
Carbon steel	4	4B	4F	4	3,4C								
Cast iron	4,3C	4,3C	4,3F	4,3C	4,3C								
Stainless steel	4B	4B	4F										
Tool steel	4F	4F	4F										
Manganese steel	4B	4B											

ELECTRODE	PREHEAT AND INTERPASS TEMPERATURE
1-ECu	A-150° F.
2-ECuSi	B-300° F.
3-ECuSn-A or ECuSn-C	C-400° F.
4-ECuAl-A	D-500° F.
5-ECuNi	F-700° F.
6-Beryllium	G-800° F.-1000° F.

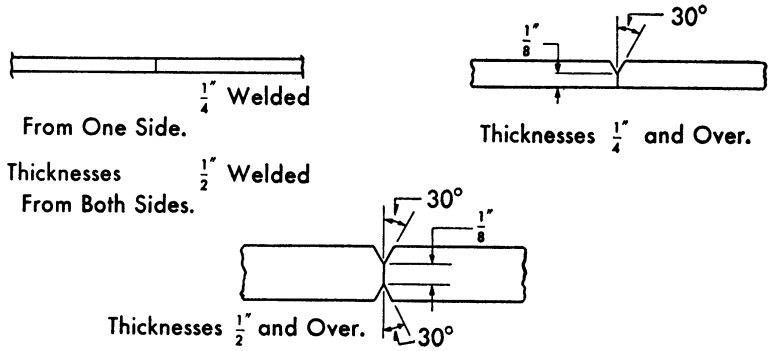
TABLE 11

JOINT PREPARATION FOR WELDING ALUMINUM

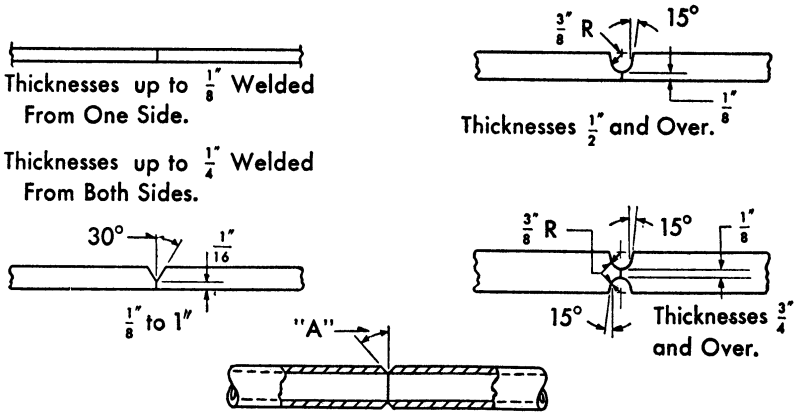
OXYHYDROGEN, OXYACETYLENE
ATOMIC HYDROGEN, CARBON ARC



METAL ARC



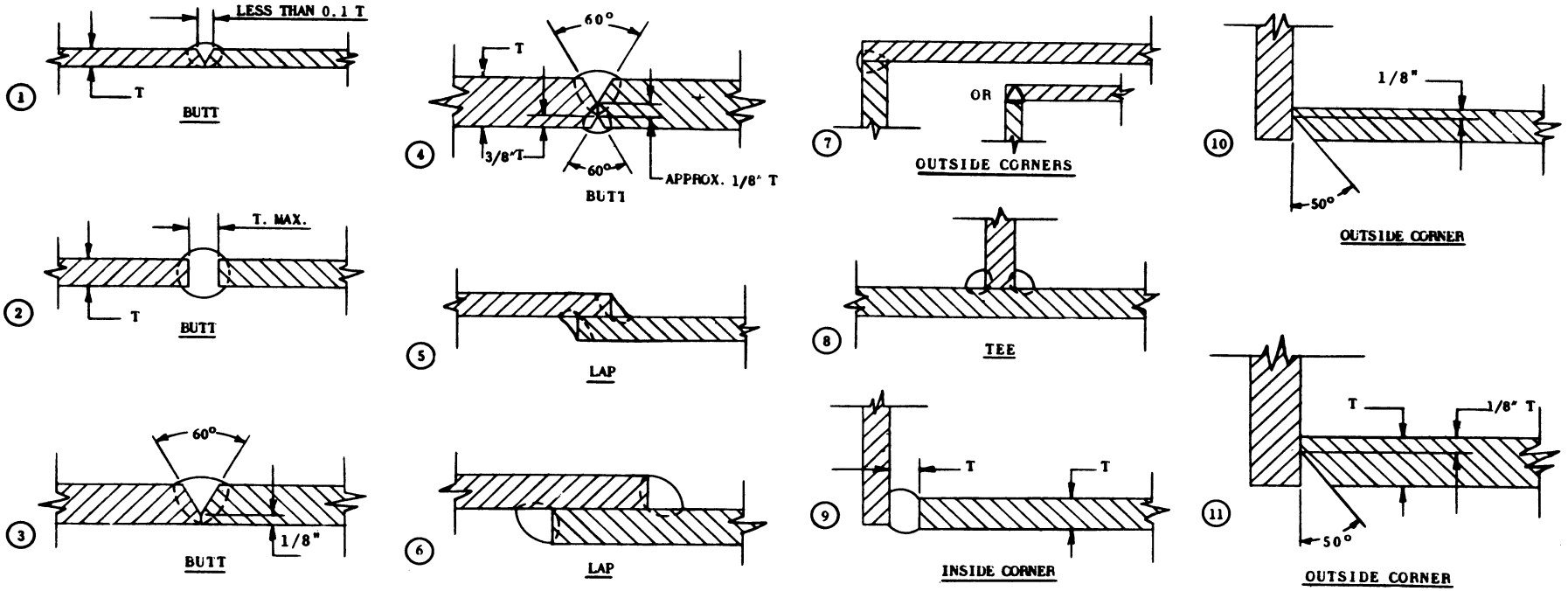
INERT GAS



Pipe Welds up to 12" I.P.S.

A = 55° Position Weld.

A = 30° Roll Weld.



"HELIARC" WELDING OF ALUMINUM

THICKNESS IN.	TYPE OF WELD	WELDING CURRENT TYPE	WELDING CURRENT AMPERES FLAT	WELDING CURRENT AMPERES VERTICAL	WELDING CURRENT AMPERES OVERHEAD	* ELECTRODE DIA. IN.	** WELDING SPEED I.P.M.	WELDING ROD MATERIAL NAME NO. ⊛	WELDING ROD SIZE IN.	GAS CUPS HW-4 TORCH CERAMIC MAX. RATING 250 AMPS AC 250 AMPS DC	GAS CUPS HW-4 TORCH WATER-COOLED MAX. RATING 300 AMPS AC 300 AMPS DC	GAS CUPS HW-5 TORCH WATER-COOLED MAX. RATING 500 AMPS AC 500 AMPS DC	ARGON FLOW AT RECOMMENDED 20 psi L.P.M.	ARGON FLOW AT RECOMMENDED 20 psi C.F.H.	REMARKS
1/16"	1,2 Butt	ALTERNATING CURRENT - HIGH-FREQUENCY STABILIZED	60- 80	60- 80 Down	60- 80	1/16"	12	AL	None or 1/16"	6	--	--	7	15	
	5,6 Lap		70- 90	55- 75 Up	60- 80	1/16"	10	AL	None or 1/16"	6	--	--	7	15	
	7 Corner		60- 80	60- 80 Up	60- 80	1/16"	12	AL	None or 1/16"	6	--	--	7	15	
	8 Fillets		70- 90	70- 90 Down	70- 90	1/16"	10	AL	None or 1/16"	6	--	--	7	15	
1/8"	1,2 Butt		125-145	115-135 Down	120-140	3/32"	12	AL	3/32" or 1/8"	7	--	--	8	17	3/32" Rod - Overhead
	5,6 Lap		140-160	125-145 Up	130-160	3/32"	10	AL	None or 3/32"	7	--	--	8	17	3/32" Rod - Overhead
	7 Corner		125-145	115-135 Up	130-150	3/32"	12	AL	None or 3/32"	7	--	--	8	17	3/32" Rod - Vertical
	8 Fillets		140-160	115-135 Down	140-160	3/32"	10	AL	1/16" or 3/32"	6 or 7	--	--	8	17	
3/16"	1,2 Butt		190-220	190-220 Up or Down	180-210	1/8"	11	AL	1/8"	8	or 8	--	10	21	
	5,6 Lap		210-240	190-220 Up	180-210	1/8"	9	AL	1/8"	8	or 8	--	10	21	
	7 Corner		190-220	180-210 Up	180-210	1/8"	11	AL	1/8"	8	or 8	--	10	21	
	8 Fillet		210-240	190-220 Up	180-210	1/8"	9	AL	1/8"	8	or 8	--	10	21	
1/4"	1,2 Butt		260-300	220-260 Up	210-250	3/16"	10	AL	1/8" or 3/16"	—	--	10	12	25	
	5,6 Lap		290-340	220-260 Up	210-250	3/16"	8	AL	1/8" or 3/16"	--	--	10	12	25	1/8" Rod_Vertical and Overhead Two Passes
	9 Corner		280-320	220-260 Up	210-250	3/16"	10	AL	1/8" or 3/16"	--	--	10	12	25	
	8 Fillet		280-320	220-260 Up	210-250	3/16"	8	AL	1/8" or 3/16"	--	--	8	12	25	1/8" Rod - Vertical
3/8"	3 Butt		330-380	250-300	250-300	3/16",1/4"	5	AL	3/16" or 1/4"	--	--	10	14	29	Two Passes
	6 Lap		330-380	250-300	250-300	3/16",1/4"	5	AL	3/16" or 1/4"	--	--	10	14	29	Two Passes
	8 Tee Fillets		350-400	250-300	250-300	3/16",1/4"	5	AL	3/16" or 1/4"	--	--	10	14	29	Two Passes
	10 Corner		330-380	250-300	250-300	3/16",1/4"	5	AL	3/16" or 1/4"	--	--	10	14	29	Two Passes
1/2"	3 Butt		400-450	290-350 Up	250-300	3/16",1/4"	3	AL	3/16" or 1/4"	--	--	12	15	31	Two or Three Passes
	6 Lap		400-450	300-350 Up	275-325	3/16",1/4"	3	AL	3/16" or 1/4"	--	--	12	15	31	Three Passes
	8 Tee Fillets		420-470	300-350 Up	275-325	3/16",1/4"	3	AL	3/16" or 1/4"	--	--	10	15	31	Three Passes
	10 Corner		400-450	300-350 Up	275-325	3/16",1/4"	3	AL	3/16" or 1/4"	--	--	10 or 12	15	31	Three Passes

⊛ *Use OXWELD No. 14 Rod for 2S & 3S Aluminum; OXWELD No. 23 Rod for all other aluminum alloys.*

* *If two sizes are listed, the smaller is for vertical and overhead welding. Use a larger electrode or slightly lower welding current when balanced-wave transformer is used.*

** *Welding speed for flat position.*

TABLE 12

TABLE 13

APPROXIMATE TIP SIZES AND GAS PRESSURES FOR GAS WELDING

METAL THICK-NESS, B. & S. Gage	OXY-HYDROGEN			OXY-ACETYLENE		
	DIAMETER OF ORIFICE in Tip, In.	OXYGEN PRESSURE, Psi	HYDROGEN PRESSURE, Psi	DIAMETER OF ORIFICE in Tip, In.	OXYGEN PRESSURE Psi	ACETYLENE PRESSURE, Psi
24-22	0.035	1	1	0.025	1	1
20-18	0.045	1	1	0.035	1	1
16-14	0.065	2	1	0.045	2	2
12-10	0.075	2	1	0.055	3	3
1/8-3/16	0.095	3	2	0.065	4	4
1/4	0.105	4	2	0.075	5	5
5/16	0.115	4	2	0.085	5	5
3/8	0.125	5	3	0.095	6	6
5/8	0.150	8	6	0.105	7	7

DATA FOR GAS WELDING TANK-TYPE STRUCTURES

GAGE, In.	GAS USED	DIAMETER OPENING Tip, In.	WIRE DIAMETER, In.	LB. WIRE/ 100 Ft. of Weld	LB. FLUX/ 100 Ft. of Weld	RATE OF WELDING Ft./Hr.
1/16	Oxy-hydrogen	0.055	0.125	6.0	2.0	12.0
1/8	Oxy-hydrogen	0.075	0.146	12.5	3.0	10.0
1/4	Oxy-acetylene	0.075	0.184	20.0	5.5	8.0
3/8	Oxy-acetylene	0.084	0.184	30.0	10.0	6.0
1/2	Oxy-acetylene	0.095	0.250	35.0	15.0	3.5
5/8	Oxy-acetylene	0.095	0.312	40.0	18.0	3.5

TABLE 14

ELECTRODE SIZES AND MACHINE SETTINGS FOR MANUAL SHIELDED METAL-ARC AND CARBON-ARC WELDING

METAL THICKNESS, In.	ELECTRODE DIAMETER, In.	APPROXIMATE CURRENT, Amp.	NO. OF PASSES		ELECTRODE CONSUMPTION Lb./100 Ft. of Weld			NO. OF ELECTRODES per Lb.
			Butt Joints	Lap and Tee Joints	Butt	Lap	Tee	
0.081	1/8	60	1	1	4.7	5.3	6.3	32
0.101	1/8	70	1	1	5.0	5.7	6.3	32
0.125	1/8	80	1	1	5.7	6.25	6.3	32
0.156	1/8	100	1	1	6.3	6.5	6.5	32
0.187	5/32	125	1	1	8.7	9.0	9.0	23
0.250	3/16	160	1	1	12.0	12.0	12.0	17
0.375	3/16 for Laps and Fillets 1/4 for Butts	200	2	3	25	29	35	17
0.500	3/16 for Laps and Fillets 1/4 for Butts	300	3	3	35	35	35	17

TABLE 15

ELECTRODE SELECTION FOR ARC-WELDING CLAD STEELS

CLADDING	COVER EXPOSED STEEL WITH 1ST PASS OR LAYER	COMPLETE BALANCE OF WELD WITH	ALLOY TO STEEL (WELDS NOT EXPOSED TO CORROSION)
405	25-20, 25-12, 18 Cr[1]	25-20,25-12, 18 Cr[1]	25-20, 25-12
410	25-20, 25-12, 18 Cr[1]	25-20, 25-12, 18 Cr[1]	25-20, 25-12
14-16 Cr	25-20, 25-12, 28 Cr[1]	25-20, 25-12, 18 Cr[1]	25-20, 25-12
430	25-20, 25-12, 28 Cr[1]	25-20, 25-12, 18 Cr[1]	25-20, 25-12
301	25-20, 25-12	25-20, 25-12, 19-9	25-20, 25-12
302	25-20, 25-12	25-20, 25-12, 19-9	25-20, 25-12
304	25-20, 25-12	25-20, 25-12, 19-9	25-20, 25-12
308	25-20, 25-12	25-20, 25-12, 19-9	25-20, 25-12
321	25-20Cb, 25-12 Cb	25-20 Cb, 25-12 Cb, 19-9 Cb	25-20, 25-12 25-20 Cb, 25-12 Cb
347	25-20 Cb, 25-12 Cb	25-20 Cb, 25-12 Cb, 19-9 Cb	25-20, 25-12, 25-20 Cb, 25-12 Cr
309	25-20	25-20	25-20, 25-12
310	25-20	25-20	25-20, 25-12
316	25-20 Mo, 25-12 Mo	25-20 Mo, 25-12 Mo, 19-9 Mo	25-20, 25-12, 25-20 Mo, 25-12 Mo
"L" Nickel	Nickel, Monel	Nickel	Nickel 80 Ni-20 Cr, 25-20 Cb, 25-12 Cb
Nickel	Nickel, 80 Ni-20 Cr[2]	Nickel, 80 Ni-20 Cr[2]	Nickel 80 Ni-20 Cr, 25-20, 25-12
Monel	Nickel	Monel	Nickel
Inconel	80 Ni-20 Cr	80 Ni-20 Cr	80 Ni-20 Cr, 25-20, 25-12

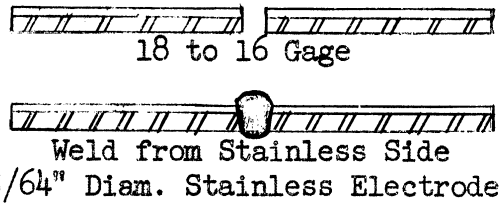
[1]Must be used under certain corrosive conditions.

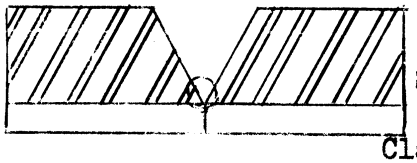
[2]May be used under certain corrosive conditions.

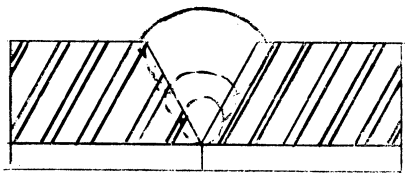
TABLE 16

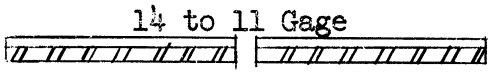
JOINT PREPARATION FOR ARC-WELDING CLAD STEELS

MANUAL PROCESS



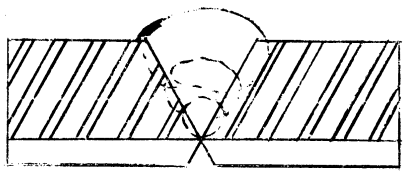






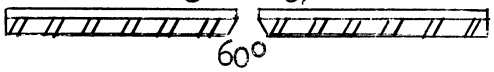
3/32" Diam. Stainless Electrode

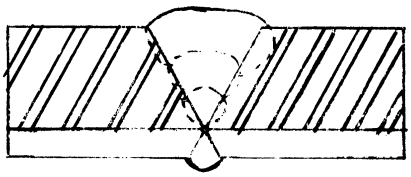
Weld from Stainless Side First
Stainless Steel Weld Throughout



3/32" Diam. Stainless Electrode

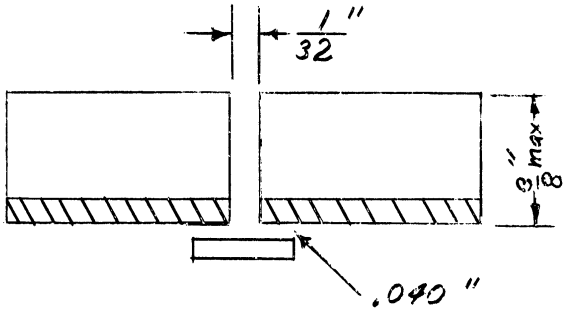
Soft Steel or Stainless Weld
10 Gage to 3/16 in.

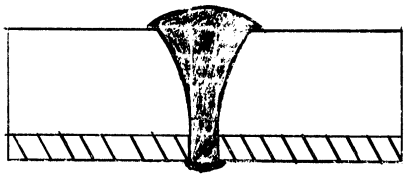




Over 3/16"

AIRCOMATIC PROCESS





Single Pass from Backing Side.

TABLE 17

ELECTRODE SIZES AND MACHINE SETTINGS FOR

ARC-WELDING CLAD STEELS

MILD STEEL

Current, Amp.

AWS TYPE	E6010	E6011	E6012	E6020	E6030
Current and Polarity	D.C., Rev.	A.C.	D.C., Str. or A.C.	D.C., Str. or A.C.	A.C. or D.C.
1/8	80-120		90-130	110-150	
5/32	120-160		120-180	130-190	
3/16	140-220		140-220	180-230	
1/4	200-300		200-300	250-330	
5/16	250-400		250-400	350-450	

ALLOY STEEL

ELECTRODE DIAMETER, IN.	CHROMIUM STEEL AND PURE NICKEL	CHROMIUM-NICKEL STEEL AND MONEL	INCONEL AND 80 NICKEL-20 CHROMIUM STEEL
1/8	90-130	70-105	80-100
5/32	125-170	100-140	110-140
3/16	160-210	130-180	140-160
1/4	200-300	240-400	--

TABLE 18

TYPICAL DATA FOR INERT-GAS-SHIELDED ARC-WELDING OF TITANIUM

	TUNGSTEN ELECTRODE	CONSUMABLE ELECTRODE
Electrode	Tungsten, 1/16 to 3/32 in. diam.	Bare titanium wire, 1/16 in. diam.
Shielding gas	Argon or helium, 15 to 35 cu. ft. per hr. (adjusted to give shiny weld-metal surface)	Argon-helium mixture, 60 to 100 cu. ft. per hr., 30 argon, 70 helium, trailing shield, 30 to 100 cu. ft. per hr.
Travel speed	4 to 25 in. per min.	10 to 20 in. per min.
Welding current	D-c electrode negative, 100 to 150 amp. at 18 to 26 arc volts	D-c electrode positive, 300 to 450 amp. at 30 to 35 arc volts
Base-metal thickness	1/16 to 1/2 in.	3/16 to 1/2 in.
Type of joint	1/16 to 1/8 in., square butt or single vee, 3/16 to 1/2 in., single or double vee	Single or double vee, 70 to 90 deg. included angle, single or multi-layer welds

TABLE 19

DUCTILE TITANIUM WELDS

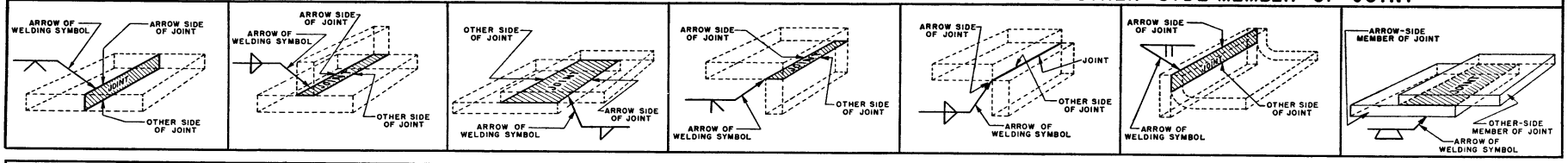
ALLOY	CONDITION	ELONGATION (%)	TENSILE STRENGTH (psi)
5% Mn (RC 130A) (Ti-7% Mn)	1340° F. - 60 min., AC	15	145,000
2.5% Cr, 1% Fe (Ti 150A)	1330° F. - 60 min., AC	11	150,000
4% Cr, 2% Mo (Ti-XCM)	As-welded	13	110,000
5% Al	1550° F. - 30 min., WQ	13	120,000
5% Cr	1330° F. - 30 min., WQ	13	110,000
5% Mo	1500° F. - 60 min., WQ	18	110,000

AC - Air Cool.
WQ - Water Quench.

AMERICAN WELDING SOCIETY

SUMMARY OF STANDARD WELDING SYMBOLS

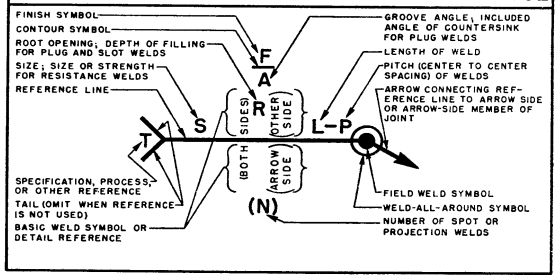
IDENTIFICATION OF *ARROW* SIDE AND *OTHER* SIDE OF JOINT AND *ARROW*-SIDE AND *OTHER*-SIDE *MEMBER* OF JOINT



BASIC WELDING SYMBOLS

LOCATION SIGNIFICANCE	ARC AND GAS WELDING SYMBOLS								RESISTANCE WELDING SYMBOLS			
	BEAD	FILLET	PLUG OR SLOT	GROOVE: SQUARE	GROOVE: V	GROOVE: BEVEL	GROOVE: U	GROOVE: J	PROJECTION	SPOT	SEAM	FLASH OR UPSET
ARROW SIDE	GROOVE WELD SYMBOL									NOT USED	NOT USED	NOT USED
OTHER SIDE	GROOVE WELD SYMBOL									NOT USED	NOT USED	NOT USED
BOTH SIDES	NOT USED		NOT USED						NOT USED	NOT USED	NOT USED	NOT USED
NO ARROW-SIDE OR OTHER SIDE SIGNIFICANCE		NOT USED	NOT USED	NOT USED	NOT USED	NOT USED	NOT USED	NOT USED	NOT USED			

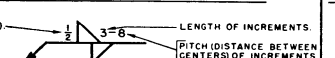
LOCATION OF ELEMENTS OF A WELDING SYMBOL



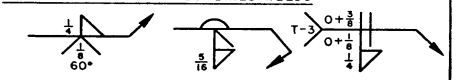
TYPICAL WELDING SYMBOLS

BEAD WELD SYMBOL INDICATING BEAD TYPE BACK WELD

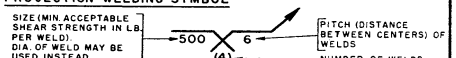
STAGGERED INTERMITTENT-FILLET WELDING SYMBOL



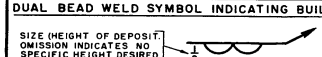
WELDING SYMBOLS FOR COMBINED WELDS



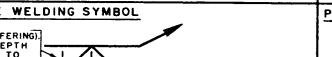
PROJECTION WELDING SYMBOL



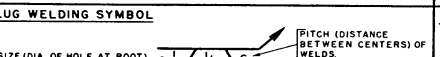
DUAL BEAD WELD SYMBOL INDICATING BUILT-UP SURFACE



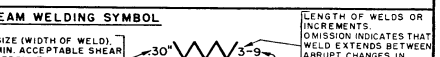
SINGLE-V GROOVE WELDING SYMBOL



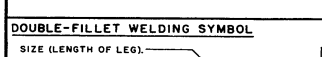
PLUG WELDING SYMBOL



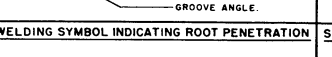
SEAM WELDING SYMBOL



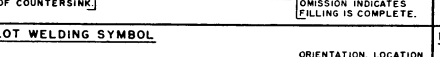
DOUBLE-FILLET WELDING SYMBOL



SINGLE-V GROOVE WELDING SYMBOL INDICATING ROOT PENETRATION



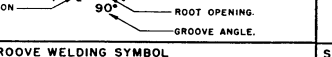
SLOT WELDING SYMBOL



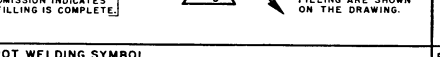
FLASH OR UPSET WELDING SYMBOL

CHAIN-INTERMITTENT-FILLET WELDING SYMBOL

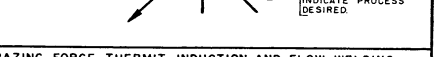
DOUBLE-BEVEL GROOVE WELDING SYMBOL



SPOT WELDING SYMBOL

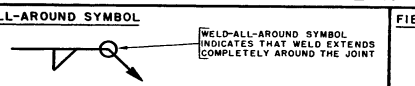


BRAZING, FORGE, THERMIT, INDUCTION AND FLOW WELDING SYMBOL

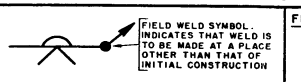


SUPPLEMENTARY SYMBOLS USED WITH WELDING SYMBOLS

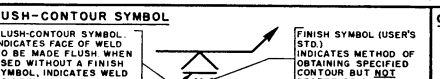
WELD-ALL-AROUND SYMBOL



FIELD WELD SYMBOL



FLUSH-CONTOUR SYMBOL



CONVEX-CONTOUR SYMBOL

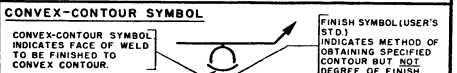


TABLE 20

BIBLIOGRAPHY

Adams, Dave, "Taming Titanium," Modern Metals, September, 1954.

American Society for Metals, Committee on Titanium, Titanium and Titanium Alloys, Metal Progress, July 15, 1954.

American Society of Mechanical Engineers, Qualification Standard for Welding Procedures, Welders, and Welding Operators, ASME, New York, 1952.

Chyle, J. J., and Kutuchief, I., "Practical Aspects of Welding Titanium Alloys," Welding Research Supplement, Welding Journal, February, 1953.

Faulkner, G. E., "The Effects of Alloying Elements on Welds in Titanium," The Tool Engineer, July, 1954.

Gilbert, Lew, Pocket Manual of Arc Welding, Industrial Book Company, 1952.

Harthblower, E. E., and Daley, Jr., D. M., "Alloy Welds Deposited in 'Un-alloyed' Titanium Base Metal," Welding Journal, July, 1954.

Ingersoll Steel and Disc Division, Borg-Warner Corporation, Manual of Welding and Fabricating Procedures for Ingaclad Stainless-Clad Steel, 1940.

International Nickel Company, Inc., Technical Bulletin T-2.

Jefferson, T. B., Welding Design Handbook, McGraw-Hill, 1948.

Jefferson, T. B., The Welding Encyclopedia, 11th Ed., The Welding Engineer Publishing Company, 1943.

Linde Air Products Company, How to Weld with Heliarc Torches.

Martin, D. C., and Voldrich, C. B., Effects of Carbon, Oxygen and Nitrogen on the Properties of Welds in Titanium Sheet, WADC Technical Report, 1952.

Meyer, H. M., and Rostoker, W., Study of Effects of Alloying Elements on the Weldability of Titanium Sheet, WADC Technical Report, 1954.

Morris, J. L., Welding Principles for Engineers, Prentice-Hall, Inc., 1951.

Revere Copper and Brass, Inc., Welding Copper, 1st Ed., 1947.

Rigsby, H. P., Welding Fundamentals, Pitman Publishing Corporation, 1948.

Stieri, Emanude, Basic Welding Principles, Prentice-Hall, Inc., 1953.

Titanium Metals Corporation, Handbook on Titanium Metal, 6th Ed., 1952.

BIBLIOGRAPHY (Cont'd.)

Watson, T. T., and Rothermel, R. R., "Aircomatic Welding of Nickel and Stainless-Clad Steels," Welding Journal, March, 1951.

Welding Handbook Committee, Welding Handbook, 3rd Ed., American Welding Society, 1950.

West, E. G., The Welding of Non-Ferrous Metals, Chapman and Hall, Ltd., 1951.